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Temporal Changes in Diet and Foraging Habitat of California Killifish (*Fundulus parvipinnis*) in Marina del Rey, California

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Abstract.—Feeding habits of the California killifish, *Fundulus parvipinnis* Girard, in Marina del Rey were examined relative to season and prey availability. Temporal changes in diet coincided with ontogenetic shifts in foraging habitats. Juvenile fish fed selectively on relatively rare planktonic harpacticoid copepods and surface dwelling insects, whereas diets of adults were dominated by benthic prey taxa, principally tanaids. The seasonal availability of some prey taxa and the active selection of others associated with a particular foraging habitat affected the type and size of prey consumed. Our results indicate that patterns of prey use are not simple responses to seasonal changes in prey abundance.

The California killifish, *Fundulus parvipinnis* Girard, is a common resident in shallow protected waters along the California coast from Morro Bay, California to Almejas Bay, Baja, Mexico (Miller and Lea 1976; Swift et al. 1993). While most abundant over muddy/sand bottoms of bays and estuaries, this small (less than 115 mm SL), short-lived (18 mo) fish may also persist in freshwater streams (Hubbs 1916; Miller 1939, 1943; Swift et al. 1993) and hypersaline ponds (Feldmeth and Waggoner 1972). Because of its ability to tolerate a broad range of environmental conditions, this species has been the focus of numerous physiological studies (Keys 1931; Wells 1935a, 1935b; Doudoroff 1945; Carpelan 1961; Hubbs 1965; Valentine and Miller 1969; Feldmeth and Waggoner 1972; Bagarino and Vetter 1992, 1993). However, far less consideration has been given to studies of its natural history, particularly feeding habits, despite its numerical dominance and important role in the structure and trophic dynamics of estuarine and bay communities (Fritz 1975; Allen 1980, 1982).

Trophic analyses of killifish collected monthly from Anaheim Bay, California from November 1969 through January 1970 by Fritz (1975) and of fish sampled bimonthly from upper Newport Bay from January through November 1978 by Allen (1980) indicate that killifish are lower trophic level carnivores consuming primarily small crustaceans (e.g., ostracods, harpacticoid copepods, gammarid amphipods), dipteran and hemipteran insects (Fritz 1975; Allen 1980), polychaetes, and gastropods (Allen 1980). However, changes in dietary patterns over time within a particular locale (Fritz 1975; Allen 1980) and differences in diets between these locations indicate that both temporal and spatial factors influence the type of prey consumed by these fish. While differences in diet within and between these sites may simply reflect a response by these fish to varying patterns of resource abundance (Moyle 1976), patterns of diet choice may also be driven by selective feeding behaviors that may change with age (ontogenetic shifts) and prey characteristics (Kaiser and Hughes 1993). Therefore, the objectives of this

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study were to assess the feeding habits of *Fundulus parvipinnis* that reside in Marina del Rey relative to season and to examine the relationship of prey type, size, and availability to dietary choices.

Methods

All field work was conducted in water depths less than 3 m just offshore of the public swimming beach located at the extreme western end of Basin D within Marina del Rey. Killifish were collected following high tides on two occasions, March 30, 1995 (1300 to 1430 hrs) and October 13, 1995 (1130 to 1300 hrs) using a 30.5 m beach seine (4.8 mm bag mesh) that was initially deployed about 10 m parallel to shore and then slowly drawn up onto the beach. A total of 129 and 150 fish were captured and immediately fixed in 10% formalin during March and October respectively.

On the October sampling date, prey resource samples were also collected from the water column and substratum in the same general area as fish captures. To obtain an estimate of planktonic prey available to fish, the water column was sampled by SCUBA divers propelling a plankton net (0.33 mm mesh) with a 0.5 m diameter mouth opening for two minutes through midwater depths (0.5 to 2.5 m). Three replicate tows were made and all samples were immediately fixed in 4% formalin. Estimates of benthic prey available were obtained by driving a 12.5 cm long benthic core (10 cm internal diameter) completely into the substratum. Three replicate cores were taken and entire samples fixed in 10% formalin. Each benthic sample (982 cm^3) was later washed through a 0.5 mm sieve and only the larger fraction was retained for further analysis.

In the laboratory, the standard length of each killifish was measured to the nearest 0.1 mm using Vernier calipers and its age determined by reading scale annuli (Cailliet et al. 1986). The entire gut and gonads were then removed from a subsample of fish selected at random from March (N = 30) and October (N = 47) collections. The dietary analysis of 30 fish taken from the March sample was considered adequate for determining large scale differences in diet between seasons, however a greater number of fish (47) were analyzed from the October sample to ascertain fine scale patterns of prey selection within a single time period. All prey were removed from each gut and identified to the lowest taxon practicable. Whole animals or heads (when prey were not intact) were counted and the greatest length of up to 25 intact individuals per taxon (as randomly encountered) was measured to the nearest 0.01 mm using an ocular micrometer. Gender and reproductive status of killifish were determined by examining the gonads for presence of eggs or sperm and scoring their stage of maturity according to the methods described by Cailliet et al. (1986). Reproductively immature fish less than one year old were considered juveniles.

The contents of planktonic and benthic resource samples collected in October were identified, counted and measured using methods similar to those described for gut content analysis. However, each planktonic resource sample was split twice with a Folsom plankton splitter so that all organisms in only one quarter of the sample were completely identified, counted, and up to 25 individuals per taxon measured. Numbers and sizes of prey for the entire plankton sample were later extrapolated. Invertebrates (>0.5 mm) contained in each benthic resource sample were separated from sand by gently floating them away from inorganic materials

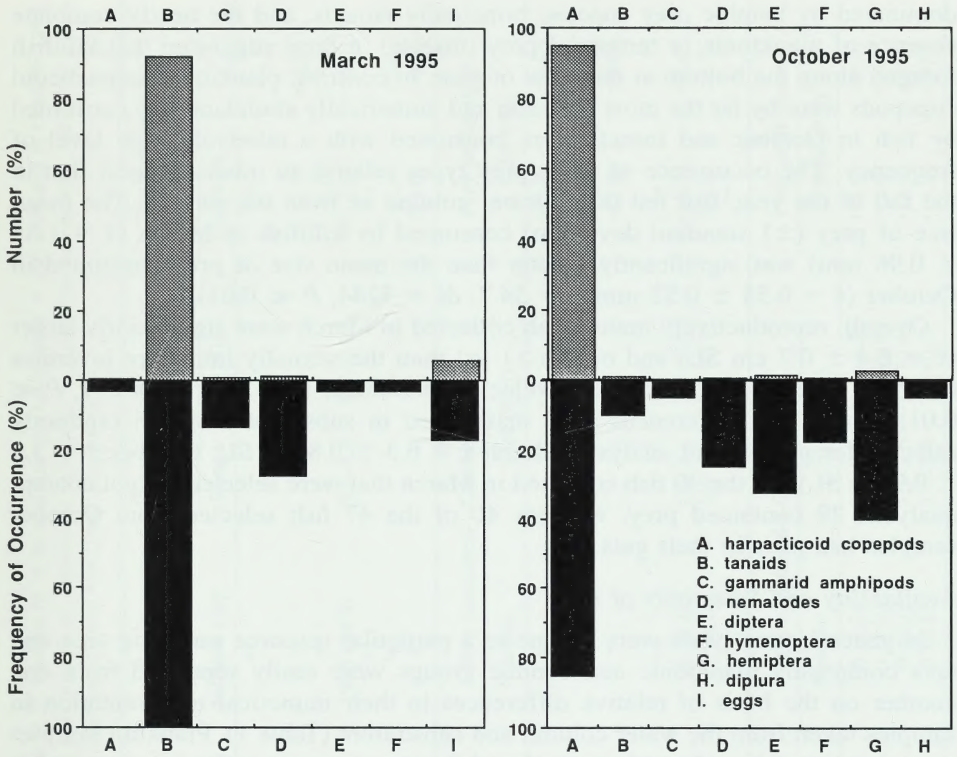

Fig. 1. Percent composition of prey by taxon, number (%) and frequency of occurrence (%) in diets of 29 killifish collected in March 1995 (N = 2107 prey) and 40 killifish collected in October 1995 (N = 2097 prey).

in distilled water. The remaining inorganic fraction was then examined for any misplaced organisms, which when found were combined with the organismal fraction that was analyzed in its entirety.

To examine the relationship between prey consumed relative to prey available, electivity coefficients were determined for all available prey taxa collected in October resource samples using Ivlev's Electivity Index (Ivlev 1961). While the sign and magnitude of resulting coefficients (from -1 to $+1$) were used as indicators of possible avoidance (negative values), random (zero values) or preferential (positive values) selection of specific prey taxa, the significance of these food preferences was statistically evaluated using a Chi Square analysis described by Pearre (1982). For these analyses, the total number of prey collected from the water column and substratum were combined and considered as a single resource base.

Results

Temporal Changes in Diet and Foraging Habitat

Although the dietary spectrum of prey taxa consumed by fish collected in March and October was similar, there was a striking difference between them in the dominant types of prey eaten (Fig. 1). The diets of killifish in March were

dominated by benthic prey species, principally tanaids, and the nearly complete absence of planktonic or terrestrial prey (insects) in diets suggested that killifish foraged along the bottom at this time of year. In contrast, planktonic harpacticoid copepods were by far the most common and numerically abundant prey consumed by fish in October and insects were consumed with a relatively high level of frequency. The occurrence of these prey types relative to others suggest that in the fall of the year, fish fed in the water column or from the surface. The mean size of prey (±1 standard deviation) consumed by killifish in March ($\bar{x}$ = 1.85 ± 0.96 mm) was significantly greater than the mean size of prey consumed in October ($\bar{x}$ = 0.55 ± 0.52 mm; t = 54.7, df = 3244, $P \ll 0.01$).

Overall, reproductively mature fish collected in March were significantly larger ($\bar{x}$ = 6.4 ± 0.7 cm SL) and older (>1 yr) than the sexually immature juveniles ($\bar{x}$ = 3.9 ± 0.9 cm SL) that were collected in October (t = 28.5, df = 277, $P \ll 0.01$). These size differences were maintained in subsamples of fish randomly selected for gut content analysis (March $\bar{x}$ = 6.3 ± 0.8 cm SL; October $\bar{x}$ = 3.9 ± 0.9 cm SL). Of the 30 fish collected in March that were selected for gut content analysis, 29 contained prey, whereas 40 of the 47 fish selected from October samples had prey in their guts.

Availability and Selectivity of Prey

In general, prey types were unique to a particular resource sampling area and taxa composing planktonic and benthic groups were easily separated from one another on the basis of relative differences in their numerical representation in samples taken from the water column and substratum (Table 1). Plankton samples were dominated by calanoid copepods, while organisms generally associated with the substratum such as tanaids, polychaetes, nematodes, and gammarid amphipods dominated benthic samples. Taxon specific differences in size and distribution strongly affected size frequency distributions of available prey (Fig. 2) such that the mean size of prey available from the water column ($\bar{x}$ = 0.82 ± 0.18 mm) was significantly less than that of benthic ($\bar{x}$ = 3.75 ± 2.35 mm) prey (t = 45.3, df = 1323, $P \ll 0.1$). Reflecting either sampling bias or low frequency of occurrence, no insects were collected in resource samples.

Killifish consumed few prey in direct proportion to their availability in the water column or substratum (Table 1). Significant electivity values indicate that in October, killifish preferentially selected relatively rare small harpacticoid copepods from the water column while they avoided relatively abundant calanoid copepods and numerically abundant benthic taxa (tanaids and polychaetes). Even though terrestrial insects were not represented in resource samples, the frequent appearance of insects in killifish guts indicate that they were probably selected whenever they were encountered. The choice of small planktonic harpacticoid copepods by fish in October strongly influenced the size range (0.2 to 5.9 mm) and mode (0.4 mm) of prey found in the guts relative to the range of sizes (0.1 to 3 mm) and mode (0.8 mm) of all planktonic prey available (Fig. 2). Although capable of consuming relatively large prey such as insects, they apparently avoided benthic prey (e.g., tanaids) within a similar size range. Thus, differences in the size frequency distributions of prey consumed relative to those of available prey resulted from the active selection of some prey taxa over others rather than the selection of large or small prey regardless of taxon or habitat.

Table 1. Total number (%) and sizes (mm) of prey represented in plankton (n = 3), benthic (n = 3), and fish gut samples (n = 29) collected in October 1995. Prey preferences are indicated by the direction of prey selection (+, significant selection; 0, no significant selection; −, significant avoidance). Electivity values (in parentheses) and significance level of food preferences based on Chi Square analyses (Pearre 1982) are also provided.

	Prey available—water column			Prey consumed—October 1995			Prey preferences	
		Size (mm)			Size (mm)		Selectivity	
Planktonic taxa	Number (%)	Range	x̄ (SD)	Number (%)	Range	x̄ (SD)	Electivity	P
Nematoda	4 (<0.1)	3.1–3.1	3.1 (0.0)	**			**	
Arthropoda:								
Cladocera	312 (0.4)	0.4–0.9	0.6 (0.2)	*			−(1.0)	<0.01
Calanoid copepods	79,164 (98.0)	0.5–1.8	0.9 (0.2)	*			−(1.0)	<0.01
Harpacticoid copepods	560 (0.7)	0.2–1.5	0.7 (0.3)	1990 (94.9)	0.3–1.0	0.5 (0.1)	+(1.0)	<0.01
Tanaidacea	120 (0.1)	0.2–1.9	1.1 (0.4)	**			**	
Urochordata: larvae	492 (0.6)	0.5–1.8	1.2 (0.3)	*			−(1.0)	<0.01
Vertebrata: fish larvae	88 (0.1)	1.6–2.8	2.3 (0.4)	*			0(1.0)	>0.05

	Prey available—substratum			Prey consumed—October 1995			Prey preferences	
Benthic taxa	Number	Size (mm)		Number	Size (mm)		Selectivity	
Foraminifera	4 (0.3)	0.6–0.6	0.6 (0.0)	*			0(1.0)	>0.05
Nematoda	122 (9.2)	2.6–12.8	6.6 (2.7)	11 (0.5)	3.3–5.9	4.3 (0.8)	+(0.6)	<0.01
Mollusca: Bivalvia	2 (0.2)	1.1–4.2	2.7 (1.6)	*			0(1.0)	>0.05
Annelida: Polychaeta	277 (20.8)	1.9–12.5	6.5 (2.5)	*			−(1.0)	<0.01
Arthropoda:								
Harpacticoid copepods	3 (0.2)	0.3–0.9	0.6 (0.3)	**			**	
Tanaidacea	873 (65.5)	0.8–4.3	2.6 (0.7)	15 (0.7)	1.2–3.1	2.0 (0.5)	−(0.3)	<0.05
Gammarid amphipods	50 (3.8)	1.0–5.1	3.1 (1.2)	3 (0.1)	1.6–3.0	2.4 (0.7)	0(0.4)	>0.05
Vertebrata: fish larvae	1 (0.1)	2.6–2.6	2.6 (0.0)	*			**	

	Prey available—water surface		Prey consumed—October 1995			Prey preferences	
Insect taxa	Number	Size (mm)	Number	Size (mm)		Selectivity	
Hemiptera	*		46 (2.2)	1.4–3.6	2.8 (1.2)	+(1.0)	<0.01
Diptera	*		21 (1.0)	0.5–3.3	1.7 (0.7)	+(1.0)	<0.01
Hymenoptera	*		9 (0.4)	1.1–2.5	1.8 (0.6)	+(1.0)	<0.01
Diplura	*		2 (0.1)	1.6–2.4	2.0 (0.6)	+(1.0)	<0.01

* Not represented in samples.

** Reported in an alternate prey resource category.

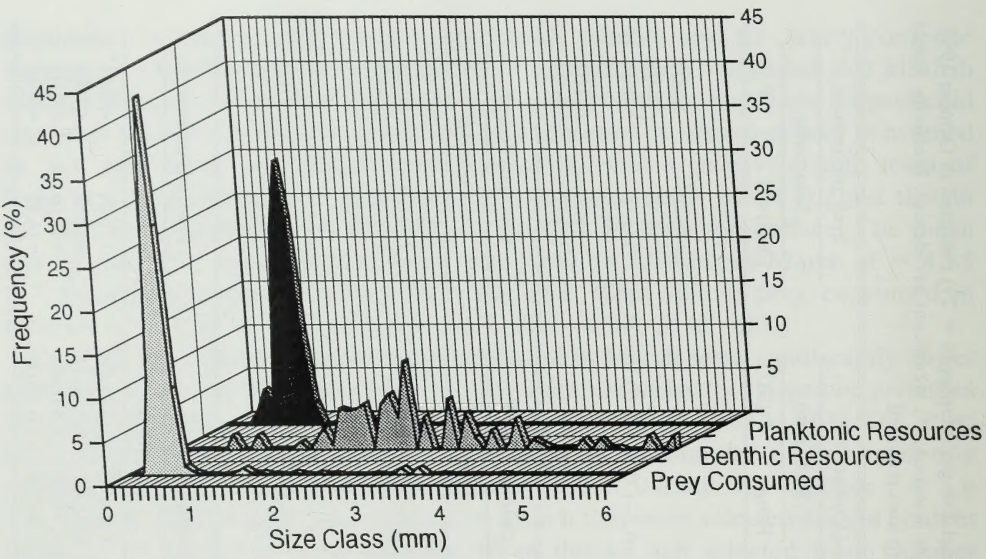

Fig. 2. Comparative size frequency (%) distributions of prey consumed by 40 killifish collected in October 1995 (N = 2097 prey) relative to prey available from the water column (N = 80740) and substratum (N = 1326). Benthic prey resources distributed in amounts less than 1% among size intervals from 6 to 12.8 mm are not displayed.

Discussion

Our results corroborate earlier descriptions of *Fundulus parvipinnis* as lower level microcarnivores that primarily consume arthropods (crustaceans and insects). Like others (Fritz 1975; Allen 1980), we observed marked seasonal changes in the presence of certain prey types (most notably insects) that contributed to dietary differences between warmer (Oct.) and colder (March) months. Yet, even within constraints imposed by the seasonal presence of certain prey types, the distinctive temporal changes we observed in the types of prey consumed by different size classes of fish signaled an age related shift in foraging habitat.

Ontogenetic shifts in diet and foraging habitats are common among fishes (Kaiser and Hughes 1993) and are likely to play a significant role in patterns of dietary choice by *Fundulus parvipinnis*. Although Fritz (1975) was unable to discern any differences in diets or foraging habitats of killifish with age or season, our results, like those of Allen (1980), indicate that juvenile killifish feed primarily on small planktonic harpacticoid copepods and gradually shift to larger benthic prey as they mature. Whether these ontogenetic shifts in diet are related to morphological changes in mouth size and/or changes in feeding behaviors remains to be determined. However, the ability of juvenile fish to consume relatively large insects indicate that they are not morphologically constrained from handling similarly sized benthic prey.

Dietary changes were coincidental with changes in foraging habitat and significant electivity values for fish obtained in October indicate that patterns of prey use were not simply a response to the numerical abundance of prey. Instead, the number, type, and size of prey consumed reflects the tendency of this species to select a unique combination of prey taxa from all prey available. Preferences of

Fundulus parvipinnis for small harpacticoid copepods and insects relative to numerically dominant prey within similar size ranges at this time (e.g., calanoid copepods and tanaids) could be related to a number of behavioral, functional, nutritional, ecological, and/or energetic factors (Kaiser and Hughes 1993). However, the assessment of these variables during ontogeny would be necessary to fully explain the value of habitat and diet changes as these fish grow larger.

For *Fundulus parvipinnis* that inhabit Marina del Rey, changes in foraging habitats and selective feeding behaviors practiced within those habitats appear to be primarily responsible for temporal changes in diet. However, other factors including temporal and spatial changes in the availability and abundance of suitable prey may be involved as well. Variations in these factors may be one explanation for dietary differences observed among fish collected at different sites and times. For example, Fritz (1975) showed that killifish in Anaheim Bay fed primarily as planktivores on harpacticoid copepods and ostracods in the spring and while not excluding these taxa, utilized a greater proportion of amphipods and insects as the year progressed. Allen (1980) reported that in addition to harpacticoid copepods, ostracods, and insects, killifish in upper Newport Bay also consumed polychaetes and gastropods frequently. The absence and relative rarity of several of these groups from our resource samples (e.g., ostracods, amphipods, and gastropods) and presence of others not seen in gut contents of fish collected elsewhere (e.g., tanaids) suggests that the composition of available prey is highly variable in time and space, and undoubtedly plays a role in prey selection of fish residing in different locations.

Conclusions

Although sampling was limited to two months of the year (March and October), temporal changes observed in the diet of killifish inhabiting Marina del Rey seem to be related to seasonal changes in the availability of certain types of prey (e.g., insects) and to shifts in foraging habitat with age. Although the causes of ontogenetic shifts in diet were not examined, a comparison of prey taxa consumed to those available in October indicate that at least juvenile killifish actively select certain prey taxa over others. We suspect that selective feeding is not limited to a single life stage or location, however spatial and temporal variations in prey availability are likely to influence prey choices and consequently dietary patterns of fish collected at different times and/or sites.

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Polychaete Fauna from San Quintín Bay, Baja California, Mexico

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Abstract.—Polychaete annelids collected in San Quintín Bay were analyzed. Thirty-nine stations were sampled with a geological type corer in December 1992, in depths of 2 to 6 m. A total of 677 polychaetes (17 families, 28 genera and 32 species) were recognized. Sixteen species and four genera were recorded for the first time in the area. The best represented families were: Syllidae (124 specimens), Lumbrineridae (100), Flabelligeridae (75), Nereididae (74), Cossuridae (73), Spionidae (58), Capitellidae (49), Cirratulidae (44) and Maldanidae (29). The most abundant species were *Scoletoma tetraura, Brada villosa, Cossura candida, Neanthes acuminata, Pionosyllis* sp., *Notomastus* sp., *Exogone lourei, Prionospio heterobranchia, Chaetozone* sp. and *Exogone dispar.*

The eastern arm of San Quintín Bay presented slightly higher values of species richness and polychaete abundances. Of the 28 families previously reported for this lagoon, 17 were found and the families Trichobranchidae and Apistobranchidae are added. To date, there are 81 polychaete species, belonging to 30 families, reported from San Quintín Bay.

Some important lagoons are located on the Pacific coast of México; these are relatively undisturbed areas, possessing high biodiversity and endemic species, and are ecologically important for several migrating bird species (Massey and Palacios 1994). They also present hydrological and sedimentary characteristics which make them ideal for aquaculture and commercial fishing. It is therefore important to obtain baseline scientific data before major development takes place. San Quintín Bay in particular represents a highly productive environment, favored by regular occurrence of upwellings which provide nutrients (Alvarez-Borrego and Chee-Barragán 1976; Ibarra-Obando 1990). It has been used for some years for bivalve aquaculture and its high diversity of marine species also makes it important for fisheries (Rosales-Casián 1996). An ambitious development project, sponsored by private interests, involves construction of two golf courses, family residences, condominiums and hotels along the barrier beach of San Quintín Bay (Pro esteros 1996). We are studying the polychaete fauna of the San Quintín lagoon complex (False Bay and San Quintín Bay) before the ecosystem is deeply disturbed.

The hydrology of San Quintín Bay has been studied extensively (Del Valle-Lucero and Cabrera-Muro 1981a, b). Overall, due to shallow depths and tidal currents, there are no significative vertical gradients regarding salinity, temperature, inorganic phosphates and silicates (Lara-Lara and Alvarez-Borrego 1975). Generally, water is renewed every 48 hours in the western arm and in a few weeks in the eastern arm (Lara-Lara et al. 1980; Monreal 1980).

Lara-Lara et al. (1980) concluded that variability at the mouth of San Quintín Bay during summer was caused by upwelling events, the tidal cycles and the solar radiation cycle. However, seasonal variability was mainly due to turbulence induced by winds and tidal currents. During spring tides, up to 80% of the bay water may go out. Usually diatoms and dinoflagellates dominate phytoplankton assemblages in the bay during summer (Silva-Cota and Alvarez-Borrego 1988).

In contrast, there is a lack of information on San Quintín macrofauna (Barnard 1970). Polychaetes constitute a very important macrofaunal group here because they comprise around 70% of the infauna biomass and individuals (Calderón-Aguilera and Jorajuria-Corbo 1986). However, only two polychaete surveys are found in the literature, one by Reish (1963) who sampled 90 stations in 1960 and the other by Calderón-Aguilera (1986, 1992) who sampled 11 stations in 1981–82 (see Table 1). The former dealt only with the eastern arm of the bay while the latter had only three stations in the western arm (False Bay).

Since the San Quintín lagoon system and southern California belong to the same biogeographic province (Brusca and Wallerstein 1979) a study of its benthic communities can be useful both to rebuild initial conditions in the polluted harbours of Newport, San Diego and San Pedro (Barnard et al. 1962) and to serve as a baseline for conditions at San Quintín Bay in the event of future development (Calderón-Aguilera 1992).

Seagrass beds are important nursery areas for many species of fish and invertebrates, including several of economic importance (Stoner and Livingston 1980; Orth and Montfrans 1990). They also help to stabilize sediments, thus reducing coastal erosion; sediment stability created by seagrass rhizomes and blades is in great part responsible for the composition and diversity of the seagrass fauna (Orth 1977).

San Quintín Bay is located on the Pacific coast of Baja California (30°24′–30°30′N, 115°57′–116°01′W). This lagoon complex has an area of 42 km^2 and about 60% of it is covered by the eelgrass *Zostera marina*. Japanese oysters *Crassostrea gigas* have been cultivated since 1980 on a small scale (Ibarra-Obando 1990); no rivers empty into the bay regularly and most of the houses along the shoreline have septic tanks, so it can still be considered a relatively undisturbed area. Intensive, large-scale oyster mariculture is being considered for the near future (Ibarra-Obando 1990). The lagoon has the shape of an "Y" with a single entrance at the base of the Y (Fig. 1). The western arm (False Bay) has an average depth of 4 m whereas the eastern arm (San Quintín Bay) has an average depth of 8 m. During low tides around 20% of the seafloor is exposed. Upwellings have been reported, in spring and summer, south of the common mouth near Punta Entrada. Granulometric studies show that clay and silty-sand predominate in shallow areas as well as toward the north within both arms. Very fine sands are more abundant near the mouth of the system. Channels are essentially located on the eastern side of False Bay, and in both arms also run along the middle region. The channel sediments are highly diverse, from medium to fine sand and silt (Barnard 1970; Calderón-Aguilera 1992). The lagoon margins and especially the northern region of both arms present a typical saltmarsh flora dominated by *Spartina foliosa* and *Salicornia virginica*.

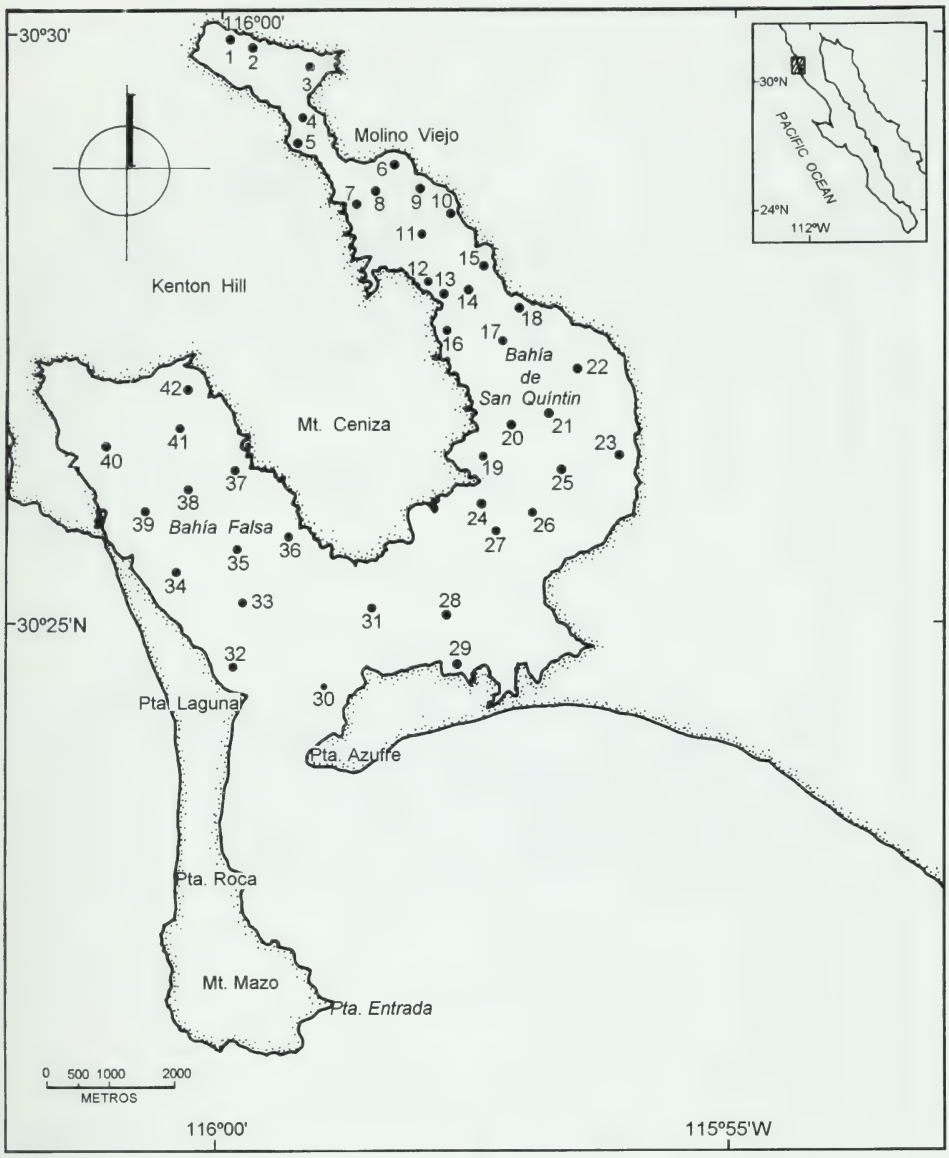

Fig. 1. Study site: sampling stations in both arms of San Quintin Bay, Baja California.

Materials and Methods

Thirty-nine stations were sampled during 10–11 December 1992, including 13 stations in the western arm and 26 stations in the eastern arm (see Fig. 1). Samples were collected with a geological corer (16 cm internal diameter, 12 cm depth, sampling area of 0.02 m^2). Temperature and redox potential were measured immediately after collection of each sample by probing 2–3 cm inside the sediments an electrode coupled to a field potentiometer and a thermometer. Sediments were sieved in the field using 1.0 mm mesh size and retained material was fixed in 7%

Table 1. Polychaete species recorded during three different studies at San Quintín Bay, Baja California. Numbers correspond to the different taxa recorded in the area.

	Reish, 1963		Calderón Aguilera & A. Jorajuria-Corbo, 1986		This work
1	*Anaitides ca. multiseriata*	48	*Aedicira pacifica*	62	*Apistobranchus sp*
2	*Anaitides williamsi*	49	*Aricidea suecica*		*Arabella iricolor*
3	*Arabella iricolor*		*Armandia bioculata*	63	*Brada villosa*
4	*Arenicola cristata*		*Axiothella rubrocincta*		*Brania sp.*
5	*Armandia bioculata*		*Brania clavata*	64	*Cirrifornia cf. spirabrancha*
6	*Axiothella rubrocincta*		*Chone mollis*		*Chaetozone sp.*
7	*Brania clavata*		*Cirrifornia luxuriosa*		*Chone sp.*
8	*Capitella capitata*	50	*Cossura soyeri*	65	*Clymenura gracilis*
9	*Capitita ambiseta*		*Eteone dilatae*		*Cossura candida*
10	*Chone mollis*		*Eteone pacifica*	66	*Euchone sp.*
11	*Chrysopetalum occidentale*		*Exogone occidentalis*	67	*Exogone dispar*
12	*Cirrifornia luxuriosa*		*Fabricia limnicola*	68	*Exogone lourei*
13	*Cirrifornia spirabrancha*		*Kinbergonuphis microcephala*	69	*Goniada maculata*
14	*Cossura candida*		*Leitoscoloplos pugettensis*		*Kinbergonuphis cf microcephala*
15	*Dorvillea articulata*		*Lepidonotus squamatus*	70	*Leitoscoloplos mexicanus*
16	*Eteone dilatae*		*Lumbrineris erecta*	71	*Lysidice ninetta*
17	*Eteone pacifica*		*Lumbrineris minima*	72	*Marphysa sanguinea*
18	*Eulalia bilineata*	51	*Magelona pitelkai*		*Megalomma bioculatum*
19	*Exogone verugera*		*Marphisa sanguinea*	73	*Monticellina tesselata*
20	*Fabricia limnicola*	52	*Mediomastus ambisetus*		*Neanthes acuminata*
21	*Glycera americana*	53	*Mediomastus californiensis*		*Nereis sp.*
22	*Goniada brunnea*		*Megalomma pigmentum*		*Notomastus sp.*
23	*Haploscoloplos elongatus*		*Neanthes arenaceodentata*	74	*Pionosyllis sp.*
24	*Lepidonotus caelorus*	54	*Nephtys caecoides*	75	*Polydora socialis*

Table 1. Continued.

Reish, 1963		Calderón Aguilera & A. Jorajuria-Corbo, 1986		This work	
25	*Lumbrineris erecta*	*55*	*Nephtys ferruginea*	76	*Praxillela sp.*
26	*Lumbrineris minima*		*Notomastus magnus*	77	*Prionospio multibranchiata*
27	*Marphysa sanguinea*		*Notomastus tenuis*		*Prionospio (Minuspio) cirrifera*
28	*Megalomma pigmentum*		*Pherusa capulata*		*Prionospio heterobranchia*
29	*Nephtys caecoides*	*56*	*Phylo felix*	78	*Scoletoma tetraura*
30	*Nereis caudata*		*Pista alata*	79	*Scoloplos ruba*
31	*Nerinides maculata*		*Platynereis bicanaliculata*	80	*Spio pettiboneae*
32	*Notomastus magnus*		*Polyophtalmus pictus*	81	*Syllis (Syllis) gracilis*
33	*Onuphis microcephala*	57	*Prionospio cirrifera*		
34	*Ophiodromus puggettensis*	58	*Prionospio heterobranchia*		
35	*Pista alata*	59	*Prionospio malmgreni*		
36	*Platynereis bicanaliculata*	60	*Prionospio newportensis*		
37	*Polydora uncata*	61	*Pseudopolydora kempi*		
38	*Polyophthalmus pictus*		*Scolelepis maculata*		
39	*Prionospio malmgreni*		*Scoloplos acmeceps*		
40	*Prionospio pygmaeus*		*Scyphoproctus oculatus*		
41	*Scoloplos (L) ohlini*		*Spiophanes missionensis*		
42	*Scoloplos acmeceps*				
43	*Scyphoproctus oculatus*				
44	*Sphaerodorum minutum*				
45	*Spiophanes missionensis*				
46	*Trypanosyllis gemmipara*				
47	*Typosyllis variegata*				

buffered formaldehyde. In the laboratory, samples were washed using a 0.5 mm mesh and transferred to 70% isopropanol. Polychaetes were then sorted and identified to species level whenever possible.

The systematic arrangement of Fauchald (1977a) for families was followed. For each species the following information is provided: the material examined including the total number of specimens collected at each station (station number in brackets); principal characteristics elaborated by direct observation of collected specimens and literature; data related to habitat, including data obtained during this survey; geographic distribution as currently recognized, including new records for the study area. For each species abundance per station is given, referring to the number of specimens/ 0.02 m^2. Abbreviations used in this paper are: Eh, redox potential (in mV); D, depth (in m); T, temperature (in °C); O.M., organic matter (% of dry weight); this last one was evaluated by ignition loss (Byers et al. 1978).

For approximately 10 species (e.g., *L. mexicanus, S. rubra, S. tetraura, C. candida, P. cirrifera*, etc.) our observations differ in some details from published descriptions, for example concerning the apparition of branchiae, number of thoracic setigers, transition thorax-abdomen, appearance of multidentate or subacicular hooks, location of ipsiloid setae, number of neurospines and notospines. These differences can be due to individual variation within a population and in some cases also to geographic variation.

Results

A total of 677 polychaetes were collected and identified, belonging to 17 families, 28 genera and 34 taxa: 32 species and two at family level (Table 1). The families best represented were Syllidae (124 specimens), Lumbrineridae (100), Flabelligeridae (75), Nereididae (74), Cossuridae (73), Spionidae (58), Capitellidae (49), Cirratulidae (44) and Maldanidae (29). Altogether these families accounted for approximately 90% of the polychaetes collected. The first four families constituted approximately 55% of the total abundance.

The Eh values were negative at most of the stations. In the eastern arm they varied between −360 mV and +168 mV; False Bay presented values that ranged from −326 mV to +181 mV. Sediment temperatures ranged between 18.9 and 21.9°C (Table 2).

The most abundant species were *Scoletoma tetraura* (100 organisms), *Brada villosa* (75), *Cossura candida* (73), *Neanthes acuminata* (72), *Pionosyllis* sp. (70), *Notomastus* sp. (49), *Prionospio heterobranchia* (34), *Exogone lourei* (34), *Chaetozone* sp. (28) and *Exogone dispar* (15) (Table 3). Of the 28 families already reported for the San Quintín lagoon system, 17 were found in the present work and two families were added: Trichobranchidae and Apistobranchidae. Of the 32 species collected, approximately 40% had not been previously reported in the system.

Families and Species Collected

Family Orbiniidae Hartman, 1942

Leitoscoloplos mexicanus (Fauchald 1972), illustrated in Mackie 1987: 11, Figs. 10 a–d.

Material examined: 3 specimens: (31) 2; (41) 1.

Characteristics: Incomplete animals with 17 to 21 setigers. Short, pointed prostomium. Peristomium without setae, transition from thorax to abdomen at setigers

Table 2. Stations location, physico-chemical parameters and granulometry at San Quintín sediments.

Station	Lat. N.	Long. W.	Eh(mV)	T°C	O.M. (%)	Sand (%)	Silt (%)	Clay (%)
1					2.35	39.86	30.86	29.28
2	30°29′34″	115°59′34″	−255	21.40	0.43	96.80	3.20	0.00
3					1.86	63.78	23.64	7.90
4	30°29′23″	115°58′57″	−184	20.80	1.33	60.08	25.81	13.61
5	30°29′06″	115°59′01″	−127	20.10	2.81	44.97	30.12	22.46
6	30°29′02″	115°58′37″	103	20.50	2.78	13.42	65.52	21.26
7	30°28′38″	115°58′26″	−150	20.50	1.91	63.79	23.38	10.21
8	30°28′45″	115°58′10″	−280	20.40	0.58	71.88	27.84	0.77
9	30°28′50″	115°57′51″	−322	20.60	2.66	36.20	36.38	22.78
10	30°28′28″	115°57′29″	168	21.40	2.37	65.82	18.78	14.63
11	30°28′18″	115°57′46″	−294	20.50	0.79	84.38	11.51	4.11
12	30°27′52″	115°57′50″	−145	19.10	0.00	25.84	66.09	8.10
13	30°27′48″	115°57′46″	−203	20.50	0.58	86.72	13.28	0.00
14	30°27′49″	115°57′30″	−320	21.00	1.55	50.59	35.64	12.80
15	30°28′02″	115°57′11″	−126	19.90	3.33	19.77	44.88	27.69
16	30°27′33″	115°57′41″	−360	20.00	3.10	96.68	3.32	0.00
17	30°27′21″	115°57′09″	−230	20.40	1.89	54.51	31.55	14.86
18	30°27′46″	115°57′06″	−200	20.40	1.40	69.61	6.59	21.57
19	30°26′32″	115°57′17″	−252	21.40	2.03	60.08	25.81	13.61
20	30°26′46″	115°57′00″	−156	20.10	0.62	74.65	25.04	2.36
21	30°26′52″	115°56′37″	−297	20.30	0.76	78.61	12.34	9.26
22	30°27′07″	115°56′17″	−30	18.90	1.68	37.77	35.52	22.97
23	30°26′33″	115°56′03″	152	19.30	1.27	42.58	40.04	25.89
24					2.23	31.95	28.86	24.06
25	30°26′22″	115°56′33″	−257	20.70	0.89	52.38	24.01	20.78
26	30°25′58″	115°56′48″	−166	21.60	0.43	97.06	2.90	0.00
27	30°25′50″	115°57′09″	−223	21.10	1.38	98.08	1.92	0.00
28	30°25′12″	115°57′31″	−136	20.50	0.48	89.05	10.95	0.00
29	30°24′32″	115°57′29″	−242	21.60	0.28	98.13	2.25	0.00
30	30°24′29″	115°58′38″	−94	20.50	0.05	71.78	17.04	8.86
31	30°25′10″	115°58′12″	−104	21.50	0.37	88.40	11.79	0.00
32	30°24′39″	115°59′46″	−174	20.50	1.99	66.82	21.80	10.39
33	30°25′12″	115°59′44″	−285	20.60	0.26	93.75	6.25	0.00
34	30°25′32″	115°00′14″	−84	21.10	2.96	51.30	36.54	12.52
35	30°25′42″	115°59′44″	−326	21.10	2.21	42.27	45.83	6.40
36	30°25′52″	115°59′12″	−104	21.50	0.53	58.99	33.54	7.03
37	30°26′21″	115°59′33″	−205	20.60	0.93	30.03	60.00	6.05
38	30°26′10″	115°59′58″	−115	21.00	2.57	39.00	46.14	15.27
39	30°26′00″	115°00′26″	−148	19.80	1.16	7.26	72.59	8.17

13–14. Branchiae present from setiger 13–14, the first short, thin and triangular; increasing in size rapidly. Thoracic notopodia with postsetal lobes thin and triangular, increasing in size along the thorax. Abdominal segments without ventral cirri. Abdominal notopodia with postsetal lobes lanceolated; neuropodia bilobed, internal lobe long and stronger. All setae similar, long and thin capillaries, each laterally crenulated and bifurcated.

Observations: Specimens had branchiae from setigers 13–14, not from setigers 11–12 as mentioned in the original diagnosis; they also present 13–14 thoracic setigers, not only 14 as mentioned in Mackie (1987).

Habitat: In deep waters, 1400 m (Fauchald 1972) and 1377–1417 m (Mackie

1987). In mud and sandy mud; D = 28.6–106.4; T = 13.2–17.5; O.M. = 1.5–6.9 (Hernández-Alcántara 1992). In mud and sandy mud; D = 20–70; T = 24–30; O.M. = 0.3–1.6 (González-Ortíz 1994). In this study, this species appeared in shallow waters, near the mouth and at the northern region of False Bay (Fig. 1), in sand and muddy-sand; D = 2–5; Eh = −104 to + 100; T = 21.5–21.6; O.M. = 0.28–2.57.

Distribution: Salsipuedes Basin, Gulf of California (Fauchald 1972); continental platform, east coast of the Gulf of California (Hernández-Alcántara 1992); Mazatlán, Morro and Salina Cruz (González-Ortíz 1994).

Scoloplos rubra (Webster 1879; Taylor 1984) 1.29, Figs. 1.28 a–d.

Material examined: 6 specimens: (31) 3; (29) 1; (15) 1; (18) 1.

Characteristics: Organisms with 160 to 248 setigers. Prostomium conical, pointed, larger than its width. Peristomium formed by one asetigerous segment. Simple branchiae present from setiger 6. Thorax with 19 to 26 setigers. Notopodia with cirriform lobes from setiger 1; thoracic neuropodia with papillae on the last setigers. Abdominal notopodia cirriform, similar to the branchiae; neuropodia with short and small presetal lobes. Thoracic notosetae are crenulated capillaries; neurosetae crenulated capillaries, grouped in 4 rows, with one acicular long and curved hook. Pygidium with four short cirri.

Observations: The specimens from San Quintín possess 19 to 26 thoracic setigers; however Taylor (1984) mentioned 23 to 28 setigers.

Habitat: Intertidal to 200 m (Day 1973; Taylor 1984), in fine sand, silty mud and sandy mud (Taylor 1984). Mud, sandy mud, muddy sand, sand, sandy gravel, D = 16.5–54; T = 17–31; O.M. = 0.42–1.25 (Rodríguez-Villanueva 1993; Miranda-Vázquez 1993). In sandy sediments, near the mouth of the bay, north of Punta Azufre, D = 5; Eh = −104; T = 21.5; O.M. = 0.28.

Distribution: Amphiamerican. Southeastern United States, Gulf of Mexico to Campeche (Fauchald 1972). Eastern Pacific, between Alaska and Mexico, North Carolina, Northern Gulf of Mexico (Taylor 1984). Coasts of Tampico, Veracruz and Campeche, Mexico (Rodríguez-Villanueva 1993; Miranda-Vázquez 1993).

Family Eunicidae Berthold, 1827

Marphysa sanguinea (Montagu 1815; Fauchald 1970) 64–66; 1977b: 42.

Material examined: 2 specimens: (6) 2.

Characteristics: Incomplete organisms up to 47–75 setigers. Bilobed prostomium, peristomium formed by two achete segments, first one double width of the second. Branchiae begin at setiger 14–19, one filament, with up to 3–4 filaments at posterior setigers. Black acicula. Subacicular simple hooded hooks present from setiger 32–35. Neurosetae with pectinate and limbate setae, compound spinigers from setiger 1.

Observations: Collected specimens had branchiae before setiger 42 and subacicular hooks at setiger 48 as mentioned by Gathof (1984); they also correspond to Fauchald (1970) who indicated that branchiae begin at setiger 24–35 in juvenile worms. Pettibone (1963) and Hartman (1944) mentioned variations regarding the start of branchiae; they appear from setiger 17 to 57.

Habitat: In shallow water up to 120 m (Pettibone 1963). Intertidal and interstitial at the west of México (Fauchald 1970); at 65 m in coarse sand (Gathof

1984); in the eastern arm of San Quintín Bay, near Molino Viejo; in silty clay. D = 4; Eh = +103; T = 20.5; O.M. = 2.78.

Distribution: English Channel, France, Mediterranean, Adriatic Sea, Massachusetts to Florida, Gulf of Mexico, Bermudas, Bahamas, West Indies, Japan, China, southern California to Mexico, Panama. Indian Ocean, Red Sea, Australia, New Caledonia, east, west and south Africa (Pettibone 1963; Day 1967). Cosmopolitan (Fauchald 1970). Pacific, Atlantic and Indian Oceans, Mediterranean Sea and Japan (Miura 1977). Southern Texas (Gathof 1984). Tecolutla, Veracruz, Mexico (Moreno-Rivera 1986) and Tamiahua lagoon, Veracruz (Nava-Montes 1989).

Family Lumbrineridae Malmgren, 1867

Scoletoma tetraura (Schmarda 1861) n. comb.

Lumbrineris tetraura (Hilbig 1995) 309–310, plate 11.13, Figs. a–g.

Material examined: 71 specimens: (2) 1; 8 (1); (11) 1; (13) 4; (16) 7; (17) 1; (19) 9; (27) 8; (31) 1; (32) 1; (33) 2; (35) 13; (37) 16; (38) 2; (40) 1; (41) 3.

Characteristics: Incomplete organisms with 32 to 220 setigers; complete organisms with 284 setigers. Prostomium rounded anteriorly. Simple hooded hooks present from setiger 1, with 8–9 distal teeth. The transition between simple hooks and posterior stouter, short hooks, between parapodia 40–60; one big rostral tooth and five small apical teeth. Anterior parapodia with truncate presetal lobes, in posterior parapodia double length of the presetal ones. Maxillary formula, I: 1, II: 4–5, III: 2, IV: 1.

Observations: Simple hooks with 5 to 8 distal teeth and not 8-9 as mentioned by Hilbig (1995). The transition of the hooks take place at setigers 17–46, this rank is different from that reported by Hilbig (1995).

Habitat: Intertidal (Fauchald 1970) to 60 m; off the coast of Zaire (ex Congo) it has been registered at 3806 m depth (Miura 1980). Flexible with regard to substratum; it has been reported from mud, sand and silty sand, D = 20–76; T = 21–30; O.M. = 0.17–1.67 (González-Ortiz 1994). In the present study the species was collected frequently from both arms of the bay. In sand, sandy-mud and muddy-sand, D = 1–5; Eh = −360 to + 100; T = 20–21.6; O.M. = 0.05–3.33.

Distribution: Africa and widespread in the Americas (Fauchald 1970); California, Peru, Chile, Argentina (Miura 1980). In the Mexican Pacific it has been registered in the east coast of the Gulf of California (Fauchald 1970; Kudenov 1973; 1975; 1980; van der Heiden & Hendrickx 1982; Arías-González 1984; Hernández-Alcántara 1992).

Family Cossuridae Day, 1963

Cossura candida (Hartman 1955, Hilbig 1996) 394–396, Figs. 9.4 a–g.

Material examined: 36 specimens: (13) 1; (16) 8; (26) 14; (27) 8; (33) 1; (35) 1; (37) 3.

Characteristics: Incomplete organisms with 20 to 65 setigers. Prostomium conical, rounded, with two peristomial segments of the same length. Tentacle inserted in setiger 3. Setae of two different types: short, coarse setae with relatively short, stiff hairs along the cutting edge located anteriorly; longer setae with a dense border of fine hairs.

Table 3. Polychaeta species abundances at San Quintín Bay.

Species/Station	2	4	6	7	8	11	12	13	14	15	16	17	18	19	22	23	26	27	28	29	30	31	32	33	35	37	38	39	40	41	To-tal
Apistobranchidae																															
Apistobranchus sp										1																					1
Capitellidae																															
Notomastus sp							5									41			2										1		49
Cirratulidae																															
Cirriformia cf. spirabrancha					5				1																1						7
Chaetozone sp	12				5		1	1	1											6					1				1		28
Monticellina tesselata								4				2						1						2							9
Cossuridae																															
Cossura candida							6	1			8						14	8	19					1	1	3			12		73
Eunicidae																															
Lysidice ninetta							1																								1
Marphysa sanguinea			2																												2
Flabelligeridae																															
Brada villosa	7		2		3	4	11		26			15							1					2				2	2	75
Goniadidae																															
Goniada maculata																					1	1									2
Lumbrineridae																															
Scoletoma tetraura	4			2	1	1	3	4	5		7	1		18				8	4			1	1	2	13	16	2		4	3	100
Maldanidae	2																		2			1				1	16	1			23
Clymeneura gracilis			1					1																			3				5
Praxillela sp.																		1													1
Nereididae																															
Neanthes acuminata	5				1			4			7			4	12		2	7		5		1							24		72
Nereis sp																							1	1							2
Oenonidae																															
Arabella iricolor			3	2	1		1	1																			1				9
Onuphidae																															

Table 3. Continued.

Species/Station	2	4	6	7	8	11	12	13	14	15	16	17	18	19	22	23	26	27	28	29	30	31	32	33	35	37	38	39	40	41	To-tal
Kinbergonuphis microcephala																		1													1
Orbiniidae																															
Scoloplos rubra							3			1			1		1					1		1									8
Leitoscoloplos mexicanus																						2								1	3
Sabellidae																															
Euchone sp							6								2																8
Megalomma bioculatum								1																				3		1	5
Chone sp								1														8					1				10
Syllidae																															
Brania sp																							1								1
Exogone lourei							5				1		18						2						1				7		34
Exogone dispar								1															1			9		4			15
Syllis (Syllis) gracilis			4																												4
Pionosyllis sp	1		65							4																					70
Spionidae																															
Prionospio multibranchiata							2			5																					7
Prionospio heterobranchia	1						7	2			8						1	2				1	1	3		2			6		34
Prionospio (Minuspio) cirrifera								1																							1
Polydora socialis															1				1	5											7
Spio pettiboneae		1						1													3		4								9
Trichobranchidae						1																									1
Total number	32	1	77	4	16	6	51	23	33	11	31	18	19	22	16	41	17	28	31	17	4	16	9	11	17	31	23	8	57	7	677

Observations: In the studied organisms the transition from thorax to abdomen took place at setiger 25–30; different from the setigers reported by Hilbig (1996):24.

Habitat: In shelf, on the continental slope and basin depths (Fauchald 1972). 11 to 2400 m; sand and sand mixed with silt-clay (Hilbig 1996). This species was collected in shallow waters, in both arms of the bay, in sandy-mud and muddy-sand, D = 1–4; Eh = −360 to −160; T = 20–22; O.M. = 0.05–3.00.

Distribution: Southern California, Cedros Island, Acapulco, Zihuatanejo, in the Central American Trench (Fauchald 1972). México, Baja California; southern and central California (Hilbig 1996).

Family Spionidae Grube, 1850

Prionospio heterobranchia Moore, 1907

Prionospio (*heterobranchia*) *newportensis* (Reish 1959) 13–1960:94. (Hartman 1969) 157, Fig. 1.

Material examined: 22 specimens: (12) 2; (13) 2; (16) 8; (26) 2; (27) 2; (31) 1, (32) 1; (33) 3; (37) 2.

Characteristics: Incomplete organisms with 24 to 46 setigers. Rounded prostomium, slightly truncated. Two pairs of black eyes, anterior pair smaller, rounded and farther apart. The caruncule extends to setiger 2, without median antenna. Five pairs of branchiae from setiger 2; pairs 1, 4, 5 pinnate and 2, 3 cirriform. Capillary notosetae limbate, larger in the setigers with branchiae, becoming smaller posteriorly; hooded hooks from setiger 36.

Habitat: Intertidal in sand and mud (Calderón-Aguilera & Jorajuria-corbo 1986). Found in both arms of San Quintín Bay in sand, sandy-mud and muddy-sand, D = 2–5; Eh = −360 to −104; T = 20–21.6; O.M. = 0.05–3.00.

Distribution: California (Macioleck 1985). From Newport, California to Panama (Calderón-Aguilera & Jorajuria-corbo 1986). In the Mexican Pacific: Bahía de Mazatlán, Sinaloa (Arías-González 1984), Bahía Concepción, Baja California Sur (Salazar-Vallejo 1985), Isla Tiburón, Punta Arboleda, Sonora and Isla María Madre, Nayarit (Hernández-Alcántara 1992).

Prionospio (*Minuspio*) *cirrifera* (Wirén 1883; Macioleck 1985) 352–355, Fig. 10 a–g

Material examined: 1 specimen: 13 (1).

Characteristics: Specimen with 23 setigers. Prostomium large and rounded, elongated posteriorly until setiger 2; two pairs of eyes in trapezoidal arrangement. Peristomium with lateral wings moderately developed, not overlaping the prostomium. Eight pairs of branchiae, all cirriform, anterior ones larger than posterior ones; not joined to the notopodial lobe. Multidentate hooded hooks present from neuropodia 13–18 and at the notopodia after setiger 26.

Observations: In the studied organism the multidentate hooded hooks were present from neuropodia 19, however the reported rank by Light (1978) goes from 13–18.

Habitat: Preference for silt and sandy silt, also found on sand and silty sand. Predominantly muddy bottoms, silty mud, off jeties, intertidal rock pools, sand. Eurybathyal, intertidal to 2500 m (Foster 1971; Light 1978). In marine and estuarine environments, from the intertidal to great depths (Calderón-Aguilera & Jorajuria-corbo 1986). From 11 to 2900 m (Maciolek 1985). Mud and sandy-mud,

D = 30–150; T = 27–28; O.M. = 0.8–1.65 (Rodríguez-Villanueva 1993; Miranda-Vázquez 1993). Collected only in the eastern arm, near Muelle Viejo, in sandy-mud, D = 5; Eh = –203; T = 20.5; O.M. = 0.80.

Distribution: Arctic; Atlantic from Greenland to South America; North Sea and English Channel; Bering Sea to Gulf of California; Queensland, New South Wales and Victoria in Australia (Light 1978; Calderón-Aguilera & Jorajuria-corbo 1986).

Prionospio (*Minuspio*) *multibranchiata* (Berkeley 1927; Macioleck 1985) 365–367, Figs. 15 a–e.

Material examined: (7 specimens): (12) 2; (15) 5.

Characteristics: Prostomium rounded, widest at level of eyes. Peristomium fused to setiger 1. Caruncule extending to 1–2 setiger. 4 eyes. Long cirriform branchiae from setiger 2, 7–9 pairs; first branchiae longer. Notopodial lamellae absent in first setiger, in the others well developed. All anterior setae capillary. Hooded hooks from setigers 12–18, in neuropodia from setigers 25–32. Sabre setae from neuropodia 12–16.

Habitat: Intertidal (Maciolek 1985). In muddy sand, D = 104 m; T = 14.2; S = 35.26; O.M. = 7.2; DO = 2.40 ml/l (Hernández-Alcántara 1992). This species was collected only in the middle region of the eastern arm, in silty-clay sediments; D = 4; Eh = −126 to −145; T = 19.1–19.9; O.M. = 3.33.

Distribution: Vancouver Island, Canada; Washington, Florida, northern Gulf of Mexico (Macioleck 1985). Concepción River, Sonora (Hernández-Alcántara 1992).

Polydora socialis (Schmarda 1861)
Polydora plena. Foster, 1971: 24–25, Figs. 22–29.

Material examined: (7 specimens): (22) 1; (28) 1; (29) 5.

Characteristics: Prostomium bilobed, with 4 eyes. Caruncule extending to setiger 4–8. Palps missing. Anterior setae all capillaries. Setiger 1 with notosetae; setiger 5 large, twice the size of preceding segments, with modified rounded hooks. Neuropodial bidentate hooks without manubrium from setiger 7, apical tooth diminishing in size in posterior segments. Branchiae from setiger 7–8 as small digitiform lobes, progressively increasing in size. Dorsal lamellae digitiform. Pygidium with one large ventral lobe fused with two smaller dorsal ones.

Observations: Hernández-Alcántara (1992) found cirriform branchiae from setiger 8 and caruncule extending to setigers 4–9, we observed branchiae from setigers 7–8 as Light (1978) and caruncule up to setiger 7.

Habitat: Intertidal to 70 m depth (Day 1973; Salazar-Vallejo 1981). In mud and silt, in lagoons (Hartman 1969). Forms silt tubes in a variety of substrates, primarily sandy silt (Reish 1968); also boring in living and dead shells (Johnson 1984). In sediments often forming large beds (Light 1978). This species was collected from middle area of eastern arm, as well as near the sea entrance, in sediments sand-silt; D = 2–3; Eh = −30 to −242; T = 18.9–21.6; O.M. = 0.3–1.68.

Distribution: Cosmopolitan. California to Chile; North Carolina and Gulf of Mexico (Day 1973); San Francisco Bay south to Oceanside (Hartman 1969). East and west coasts of North America, Falkland Islands (Johnson 1984). New South

Wales, Victoria, New Zealand, North and South America (Blake & Kudenov 1978).

Spio pettiboneae (Foster 1971; Johnson 1984) 6-63, 6-65, Figs. 6-54 a–e.

Material examined: 9 specimens: (4) 1; (13) 1; (30) 3; (32) 4.

Characteristics: Incomplete organisms with 18 to 41 setigers. Head and anterior segments with brown pigment pattern. Prostomium anteriorly inflated, rounded, with caruncule. Two pairs of eyes, anterior pair larger and farther apart. Well developed peristomium, nucal organs extending on to setiger 3. Branchiae present, those on setiger 1 smaller than those on the following setigers. Anterior setae unior bilimbate, arranged in two rows. Ventral sabre setae. Tridentate hooded hooks first replacing posterior row of capillary neurosetae on setiger 11–15.

Observations: Hooded hooks began at neuropodia 11–13; Johnson (1984) reported they begin at 11–15.

Habitat: Intertidal to 120 m. Predominately in fine and medium sand; also in silty sand (Johnson 1984). In sand and sandy-mud, D = 28–46; T = 27–28; O.M. = 0.21–1.0 (Rodríguez-Villanueva 1993). This spionid species was collected in the head and the middle area of San Quintín arm and at the mouth of the bay, in sandy and sandy-mud sediments, D = 1–5; Eh = −203 to −94; T = 20.5–21.5; O.M. = 0.43–1.40.

Distribution: North Carolina and Gulf of México (Foster 1971; Day 1973; Johnson 1984), western Baja California, Mexico.

Family Cirratulidae Carus, 1863

Monticellina tesselata (Hartman 1960; Blake 1996) 328–330, Figs. 8.27 a–f.

Material examined: 9 specimens: (13) 4; (17) 2; (27) 1; (33) 2.

Characteristics: Incomplete organisms with up to 42–63 setigers. Conical prostomium, rounded apically, without eyes. Long peristomium, no rings were observed. One pair of palps inserted dorsoventrally. Branchiae from the first setiger; inserted above the notopodial base. Notosetae long and slender, forming tufts in anterior and middle regions. Neurosetae shorter and fewer; those in posterior segments geniculate, with serrated edges.

Observations: In the studied specimens the location of the tentacular palps was not clearly observed perhaps partly due to the bad state of the material; Blake (1996) said they insert at the posterior margin of the peristomium. The dorsal ridge along the thoracic region was not observed, but its presence is only mentioned by Blake (1996). Hartman (1969) does not mention it.

Habitat: On shelf and slope depths, from shallow water to great depths. In silty and muddy sediments (Hartman 1969; Blake 1996). In sand and muddy sand, D = 39–72; T = 21–30; O.M. = 11–0.94 (González-Ortiz 1994). Eastern arm and near the mouth of San Quintín system, in sandy-mud and muddy-sand, D = 2–5; Eh = −285 to −200; T = 20.4–21.1; O.M. = 0.5–3.33.

Distribution: Southern California (Hartman 1968) to western Mexico: Continental shelf of the Gulf of California (Reish 1968; Van Der Heiden & Hendrickx 1982; Arías-González 1984; Lezcano-Bustamante 1989; Hernández-Alcántara 1992) and Gulf of Tehuantepec (González-Ortiz 1994); central and southern California (Blake 1996).

Cirriformia spirabrancha (Moore 1904; Blake 1996) 361–363, Figs. 8.42 a–f.

Material examined: 7 specimens: (8) 5; (14) 1; (35) 1.

Characteristics: Incomplete organisms with 82–96 setigers, complete worms with 118–152 setigers. Rounded prostomium, without eyes. Long peristomium with 3 segments forming a protuberance which extends up to setiger 5, where both tuffs of tentacular filaments are already observed. Branchiae appear at setiger 5. Neuroacicular spines from around setigers 40–45, in the first 3–5 per fascicule, increasing to 5–6 from setigers 100 to 150; notoacicular spines beginning posterior to setiger 60–70.

Observations: In the observed specimens neurospines begin at setigers 17–23 and notospines at setigers 26–40; in the first fascicles there are one or two spines, posteriorly we acknowledged 4–5 per fascicule, not in the number and order mentioned by Blake (1996). He also said that *Cirriformia spirabrancha* has been confused with *Cirriformia moorei* due to reports of the last species in muddy sediments, in estuaries and associated with *Zostera marina* as opposed to *C. spirabrancha*, which has only been reported in hard substrates (rocks, gravel at exposed beaches).

Habitat: Inhabits tide pools in the rocky intertidal on semi-exposed shores. In crevices and under rocks (Blake 1996). Our specimens were collected principally at sandy mud with some shell fragments, middle region of western and eastern arm, D = 2–5; Eh = −280 to −326; T = 20.4–21.1; O.M. = 0.58–2.21.

Distribution: Northern, central and southern California (Blake 1996).

Family Maldanidae Malmgren, 1867

Clymenura gracilis (Hartman 1969):439, Figs. 1–4.

Material examined: 5 specimens: (13) 1, (6) 1, (38) 3.

Characteristics: Organisms with 10–13 setigers. Cephalic plaque with smooth, wide flange almost all around. Long nuchal organs, extend through ⅔ of cephalic plaque. Without eyes. Buccal segment as long as first and second setigers, followed by 5 shorter segments, setigers 9 to 13 longest. First setiger with few uncini increasing to 6 in a row in second setiger. Setigers 7 and 8 with glandular bands.

Habitat: In shelf and canyon depths, in silty mud and green sand. Constructs a friable tube of silt and gravel (Hartman 1969). In San Quintín at 3–5 m depth, in the middle area of both lagoon arms, in sandy mud and muddy sand. D = 3–5 m; Eh = −203 to +103; T = 20–21; O.M. = 0.6–2.6.

Distribution: Southern California (Hartman 1969). San Quintín lagoon, Baja California.

Family Syllidae Grube, 1850

Exogone dispar (Webster 1879; Uebelacker & Johnson 1984) 30–42, 30–43, Fig. 30–36 a–e.

Material examined: 15 specimens: (13) 1; (32) 1; (37) 9; (39) 4.

Characteristics: Incomplete organisms with 44–48 setigers. Rectangular prostomium with two pairs of eyes in trapezoidal arrangement. Pharynx extends to setigers 3–5, with a subterminal tooth. Extended proventriculus up to setigers 3 to 6 or 4 to 7. Antenna rising from anterior part of prostomium, median antenna fusiform, short palps, lateral antenna small and digitiform. Palps completely fused

dorsally. Dorsal and ventral tentacular cirri digitiform; dorsal cirri present in all setigers. Compound setae with 1–2 superior spinigers per fascicle and one small bidentate seta. Compound falcigers, all distally bidentate with primary tooth terminal. Simple ventral setae bidentate.

Habitat: Intertidal to 130m (Day 1973). From shallow waters to 5023 m; in sandy shell, sand and corals (Uebelacker & Johnson 1984). Middle area of eastern arm and western arm; in sand and sandy-mud, D = 1–5; Eh = −326 to −174; T = 19.8–20.6; O.M. = 0.53–2.96.

Distribution: Arctic, North Pacific, North Atlantic, Maine to Florida, Gulf of Mexico; Alaska to the Pacific coast of Mexico, Galápagos; South Japan and southern Africa (Day 1973; Uebelacker & Johnson 1984).

Exogone lourei (Berkeley & Berkeley 1938; Kudenov & Harris 1995) 15–17, Fig. 1.3 a–f.

Material examined: 2 specimens: (16) 1; (35) 1.

Characteristics: One complete polychaete with 43 setigers, one incomplete with 25 setigers. Cylindrical body. Prostomium wider than long; two pairs of eyes, anterior pair largest, arranged trapezoidally. Antennae located in front of anterior pair of eyes. Medium antenna fusiform, twice as long as paired lateral antennae, with a distal papillae. Palps long and fused. Proventriculus cylindrical, shorter than pharynx. Parapodia with compound spinigers, falcigers and simple setae. Compound falcigers distally bidentate; secondary tooth larger than primary. Ventral setae curved and distally bidentate. Dorsal and ventral cirri digitiform; dorsal cirri on all setigers. Natatory setae present from setiger 17. Pygidium with a pair of cirriform anal cirri.

Habitat: Lower intertidal to 40 m. Calcareous crusts, silty sand, coarse black sand, gravel with mud; mud. In the middle area of both arms of San Quintín system, in sandy-mud, D = 4–5; Eh = −360 to −320; T = 20–22; O.M. = 0.79–1.99.

Distribution: Spain. Atlantic: Gulf of Mexico, Belize, Cuba, Canary Islands; Pacific: south of British Columbia to southern California (Nuñez et al. 1992); María Madre island, Nayarit (Góngora-Garza 1984). Washington, Oregon, California, Gulf of Mexico: Texas, Louisiana, Mississippi, Alabama, Florida; Cuba; Spain (Kudenov & Harris 1995).

Syllis (*Syllis*) *gracilis* (Grube 1850; Gardiner 1976) 139, Fig. 12 l–n.

Material examined: 4 specimens: (6) 4.

Characteristics: Complete specimens with up to 73 setigers, incomplete organisms with 37–63 setigers. Prostomium rounded with four small eyes; one median antenna with 7–22 articles and two lateral antenna with 7–12 articles. Proventricle extending two setigers. Triangular palps; dorsal and ventral tentaculat cirri articulated. Ypsiloid setae between setigers 17–20. Pygidium with a pair of articulated anal cirri.

Observations: Studied specimens presented ypsiloid setae between setigers 17 and 20, whereas Uebelacker (1984) mentioned they are present between setigers 14 and 21.

Habitat: Shallow water to 235 m; among ascidians, algae, serpulid tubes, rocks, barnacles, oysters, hydroids, broken shells; on pillings. Coarse to fine-very fine

sand, silty fine to very fine sand (Uebelacker & Johnson 1984). In the eastern arm, near Molino Viejo; silty clay, D = 3; Eh = +103; T = 20.5; O.M. = 2.80.

Distribution: Cosmopolitan in temperate and tropical seas (Uebelacker 1984).

Family Nereididae Johnston, 1845

Neanthes acuminata (Ehlers 1868; Taylor 1984) 31–15, Fig. 31–14 a–e.

Material Examined: 26 specimens: (8) 1; (13) 4; (16) 7; (19) 4; (26) 2; (27) 7; (31) 1.

Characteristics: Organisms 27 to 42 setigers. Prostomium short, wide posteriorly. Tentacular cirri short. Oral ring of pharynx completely encircled by five or more rings of paragnaths. Group I = a line of four points or 8–12 in oval group, II = a wedge shaped group, III = an oval group of about 20, IV = a triangular group of about 20, V, VI, VII and VIII form a complete band of several irregular rows of roughly equal points. Parapodia similar in all body regions. Notopodia with well developed pre- and post-setal lobes. Neuropodia with longer presetal and shorter postsetal lobes. Neurosetae include homogomph spinigers and heterogomph falcigers.

Habitat: Littoral zone to 100 m. Occurs in fine to coarse sediments, often associated with vegetation (Day 1973; Taylor 1984). In mud, sand and silty clay (Fauvel 1923). Species frequently found along the middle area of the eastern arm, in sand, sandy-mud and muddy sand, D = 1.5–5; Eh = −360 to −100; T = 20–21.6; O.M. = 0.28–2.78.

Distribution: Cosmopolitan in temperate and tropical seas. North Atlantic (English Channel to Santander); Massachusetts to Florida; Mediterranean (France, Italy, Monaco); Southern California to Mexico; Tasmania and New Zealand (Day 1973; Taylor 1984).

Family Goniadidae Kinberg, 1866

Goniada maculata (Örsted 1843; Hilbig 1994) 226–228, Figs. 7.5 a–l.

Material examined: 2 specimens: (30) 1; (31) 1.

Characteristics: Organisms with 116 and 128 setigers. Body slender, prostomium conical with up to 10 short rings, four biarticulate antennae. Eyes absent. Short proboscis; terminal jaws surrounded by 18 papillae; chevrons numbering 8 to 9 on each side, largest pieces in the middle of the group. Parapodia about twice as long as body width in posterior part of the body; uniramous through setiger 23 to 37. Notopodia with digitiform presetal lobe. Dorsal and ventral cirri digitiform and of subequal length. In anterior parapodia few falcigers; notosetae short, serrated capillaries; neurosetae compound spinigers and falcigers present in anterior parapodia.

Observations: The studied polychaetes presented 9 chevrons on each side, and were uniramous through setigers 35–38. Hilbig (1994) also mentioned uniramous through setigers 23 to 37.

Habitat: Intertidal to 3000 m. Occurs in silt, sand and shelly sand (Gardiner 1976; Hilbig 1994). In sandy mud and muddy sand by D = 25–40; T = 28–31; O.M. = 0.40–0.60 (González-Ortiz 1994). South region of San Quintín arm, in sand, D = 4; Eh = −94 a −104; T = 20–22; O.M. = 0.40–0.50.

Distribution: Cosmopolitan (Gardiner 1976). Arctic Ocean: Greenland, Davis

Strait; Atlantic Ocean: western Europe and Gulf of St. Lawrence, and U.S. coast to North Carolina; Pacific Ocean: Alaska to California and Japan, Gulf of Iran, Arabian Sea, Iran coast and South Africa (Hilbig 1994), and Gulf of Tehuantepec (González-Ortiz 1994).

Family Onuphidae Kinberg, 1865

Kinbergonuphis microcephala (Hartman 1944; Fauchald 1982) 24, Fig. 5a.

Material examined: 1 specimen: (27) 1.

Characteristics: Specimen with 36 setigers. Outer lateral antennae reaching setiger 2, inner lateral antennae reach about setiger 7 and median antenna reaches setiger 4. Ceratophores have four rings. No eyes were observed. Branchiae are first present from setiger 6; maximum number of branchial filaments is seven; branchiae absent on the second half of the body. Ventral cirriform cirri present in the first 2 setigers; postsetal lobes digitiform in first 10 setigers, tridentate compound hooks in the first 3 setigers, large hooks are present from setiger 5 to 22. Compound spinigers absent. Subacicular hooks present from setiger 23. Each pectinate setae posses about 10 teeth. The maxillary formula is 1 + 1, 9 + 8, 9 + 0, 6 + 9 and 1 + 1.

Observations: Our specimens differ from *K. microcephala* in that subacicular hooks begin at setiger 23 not at 26 and the large hooks appear from setiger 5 to 22. No eyes were observed; outer lateral antenna reach setiger 2, inner lateral antenna reach about setiger 6 and median antenna reaches setiger 4.

Habitat: In intertidal sands (Fauchald 1968). Collected in the south half of San Quintín arm, in mud and sand, D = 4; Eh = −220; T = 21; O.M. = 2.23.

Distribution: Gulf of California (Fauchald 1982) and San Quintín system, Baja California.

Family Oenonidae Kinberg, 1865

Arabella iricolor (Montagu 1804; Uebelacker & Johnson 1984) 42-5, Figs. 42-2 a–f.

Arabella (*Arabella*) *iricolor*. Hilbig, 1995:320–321, Figs. 12.1 a–g.

Material examined: 3 specimens: (8) 1, (13) 1, (38) 1.

Characteristics: Incomplete organisms with 86 to 146 setigers, complete animals with 198 to 213 setigers. Elongated, cylindrical body; iridescent, brown or light yellow. Conical prostomium, longer than wider, without antenna or palpes. No eyes. Peristomium with two rings, the same size as other setigers. Parapodia with short dorsal cirri and without acicular spines. Aciculae distally spotted. Mandibles dark brown or black with light points. MI = 1 + 1, short, falcated with 6–7 basal teeth; MII = 10–11 + 10–12 asymmetrical, right largest; MIII to MV symmetrical, MIII = 6 + 6 rounded, bearing 5 small teeth and 1 bigger; MIV = 4 + 4; MV = 1 + 1 single, long pointed tooth arising from small base. Maxillary support long and large in the superior part, branches slightly separated.

Observations: Our specimens had no eyes, organisms described by Hilbig (1995) had four subequal eyes in a strait line along the posterior margin of the prostomium.

Habitat: Intertidal to 85 m; among shells, oysters, among *Zostera* holdfasts, bryozoans and algae. In mud, sand, muddy sand and sandy gravel (Uebelacker

& Jones 1984). In fine sand; D= 22.2–101; T = 13.2–16; S = 34.8–35.5; O.M. = 2.4–5.7 (Hernández-Alcántara 1992). In muddy sand, D = 22.2–101, T = 17.3–27.2; O.M. = 0.12–5.7 (González-Ortiz 1994). Intertidal to 90 m. Burrows deeply into mud, sand and gravel; it is also found under rocks; in oyster and mussel beds, among bryozoans and other colonial animals (Hilbig 1995). Middle region of both arms of San Quintín system, in muddy sand, D= 1–5; Eh = −280 to −110; T= 20.4–21; O.M. = 0.79–2.78.

Distribution: France, England, Mediterranean Sea, Massachusetts to Florida, western Mexico (Fauchald 1970). Cosmopolitan in temperate and subtropical waters (Uebelacker & Johnson 1984). Baja California (Reish 1963; Fauchald 1970; Rioja 1947, 1962; Salazar-Vallejo 1985; Hernández-Alcántara 1992); Sinaloa (Rioja 1962; Fauchald 1970; Hernández-Alcántara 1992). Gulf of Mexico, Colombia and Venezuela; Vancouver Island to California; Mexico, Argentina; Japan, China, Persian Gulf, Red Sea, Indian Ocean; Strait of Magellan; West and South Africa (Hilbig 1995).

Family Flabelligeridae Saint-Joseph, 1894

Brada villosa (Rathke 1843; Milligan 1984) 47-13, 47-15; Figs. 47-10 a–d.

Material examined: 26 specimens: (8) 3; (11) 4; (17) 15; (33) 2; (41) 2.

Characteristics: Incomplete animals with up to 26–93 setigers. Body cylindrical, slightly flattened ventrally. Dorsal surface encrusted with sand grains. Papillae cirriform densely distributed. Ventral papillae similar in shape but shorter and less dense. Filiform branchiae arranged in two lateral groups. Eyes absent. All setae simple capillaries, crossbared; those from setiger 1 longer, projecting forward forming the cephalic cage which is weakly developed. Neurosetae slightly shorter and stouter than notosetae. Conical nephridial papillae present ventrally.

Habitat: From shallow waters to 2000 m. Occurs in mud, gravel, sand, silty sand, clayey silt and rocks (Milligan 1984). In silty sand, D + 37.2; T = 15.1; S = 35.5; O.M. = 7.2 (Hernández-Alcántara 1992). Occurred in both arms of the bay, in sandy mud and muddy sand, D = 1–5; Eh = −285 to +110; T = 20.4–21.6; O.M. = 0.05–3.33.

Distribution: Cosmopolitan (Milligan 1984). Northern Gulf of California (Hernández-Alcántara & Solis-Weiss 1993).

Family Sabellidae Malmgren, 1867

Megalomma bioculatum (Ehlers 1887; Uebelacker & Johnson 1984) 54-27, 54-30, Figs. 54-22 a–g.

Material examined: 5 specimens: (13) 1; (39) 3; (41) 1.

Characteristics: Incomplete organisms 25–27 setigers. Collar bilobated, dorsal edges rounded and well separated; ventral edges prolonged as two triangular lobes. Radioles numbering 6–15 pairs, with 1–2 transverse brown bands. Dorsalmost pair of radioles bearing two subterminal, large rounded eyes. Palps long, triangular, brown. Thorax with eight setigers. Thoracic notopodia with numerous slender limbate setae; thoracic neuropodia with an anterior row of companion setae and a posterior row of avicular uncini with long handles and crest of small teeth. Abdominal notopodia with avicular uncini with short handles and neuropodia with limbate setae.

Habitat: In depth of 10–200 m. In sand, silt and clay (Uebelacker 1984); 90–200 m (Perkins 1984); sandy mud, muddy sand, gravel and sandy gravel (Uebelacker & Johnson 1984). Found south to Muelle viejo in San Quintín arm and near the head of False Bay, in sandy mud and muddy sand, D = 1–6; Eh = −200 to +110; T = 19.8–21.8; O.M. = 0.53–2.57.

Distribution: Veracruz (Rioja 1946). Gulf of Mexico, Florida, North Carolina. Tropical western Africa (Uebelacker & Johnson 1984).

Discussion

Of the 677 annelids collected, 16 new records of polychaete species and 4 records of new genera for the San Quintín lagoon system were found: *Leitoscoloplos mexicanus, Scoloplos rubra, Scoletoma tetraura, Monticellina tesselata, Exogone dispar, Exogone lourei, Goniada maculata, Clymenura gracilis, Brada villosa, Prionospio multibranchiata, Spio pettiboneae, Polydora socialis, Cirriformia cf spirabrancha, Syllis (Syllis) gracilis, Lysidice ninetta, Marphysa sanguinea, Praxillela* sp., *Apistobranchus* sp., *Pionosyllis* sp., *Euchone* sp., and one unidentified species from the family Trichobranchidae. This last family together with Apistobranchidae are reported for the first time from San Quintín; unfortunately the organisms were damaged and could not be identified to species level.

Of the 28 polychaete families previously reported for San Quintín, 17 were found in the present study and two were added. Of the 32 identified taxa, only twelve had been previously reported in the lagoon system (Reish 1963; Calderón-Aguilera & Jorajuria-Corbo 1986). Until now 30 families and 81 species of polychaetes have been recorded in the area (Table 1).

The differences among the three studies at San Quintín may indicate anthropogenic modifications and/or environmental changes which may have affected the lagoon system over the last 30 years. Nevertheless, they may also be due to insufficient sampling effort. The first reported sampling took place in the eastern arm (Reish 1963) and only one other sampling is reported in the literature, with a reduced number of stations (Calderón-Aguilera & Jorajuria-Corbo 1986). Considering the previous study of the area it may be that the new records reported here are due to a more balanced sampling effort in both arms of the lagoon system. However, it is possible that the previous authors found more species because they used a 0.5 mm mesh which allowed them to retain young worms and smaller species.

Most species presented densities of 1–10 individuals/0.02 m^2, nevertheless five species corresponded to the class of 71–100 individuals/sample (3500–5000 ind./m^2): *Scoletoma tetraura, Brada villosa, Cossura candida, Neanthes acuminata*, and *Pionosyllis* sp., these are consistent with an extremely rich fauna. When species richness per station was plotted we found that two stations (12 and 13), located in the middle region of the eastern arm presented the highest species richness with 12 and 14 species respectively. Nine stations showed intermediate values (6 to 8 species/station), whereas the 19 remaining stations presented low species richness values going from 1 to 5 species per station.

Conditions in the western arm might favor the development of the more sensitive species, those which cannot tolerate low oxygen concentrations, because here water is exchanged with the sea at a higher rate. In this study most of the species were found in fine-grain sediments, predominantly muddy sand and sandy

mud, with moderately negative Eh values. Only three stations presented positive Eh values (station 6, 103 mV, station 10, 168 mV and station 23, 152 mV). Only four stations (8, 12, 37, 38) were located in the edges of *Zostera* beds so we can not say much about polychaete composition in this habitat.

In conclusion there is still a lot of work to be done in San Quintín Bay. Not only listing the species inhabiting the area but also analyzing their structure and organization. The fact that we found 20 taxa and two families not previously reported in this area is probably due to anthropogenic modifications in the last years. Nevertheless, after examining these results it is evident that there is a need for extensive research in the coastal lagoons of Baja California in order to acknowledge their biodiversity and also for the local authorities to adequately manage their resources.

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Cetaceans of Isla De Guadalupe, Baja California, Mexico

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Isla de Guadalupe (29°00′N, 118°15′30″W) is located 240 km west of Baja California, México. The island lies within the California Current, with an average sea surface temperature of 18°C (range: 16°C spring, 20°C summer; Lynn and Simpson 1987). Northwesterly winds predominate (Berdegué 1957). The orientation of the island and its elongated shape (35 km long and 6.5–9.5 km wide) acts as a barrier against the flow of the current which produces a series of swirls at different depths. The island is surrounded by depths of 3600 m or more. The island does not have a shelf around it with exception of the southern tip were a 4 km wide and 200 m deep shelf is found between Isla Guadalupe, Isla Zapato and Isla Toro. The coastline and nearshore physiography is composed of loose basaltic rocks and boulders bounded by towering cliffs (Pierson 1987).

The only report of cetaceans near Isla de Guadalupe is by Fleischer (1978), who reported two minke whales (*Balaenoptera acutorostrata*) 500 m offshore and bottlenose dolphins (*Tursiops* sp.) on several occasions. Other reports on marine mammals in the area exist (i.e. Mangels and Gerrodette 1994), but they are far offshore from the island.

Our study was carried out while studying Guadalupe fur seals, *Arctocephalus townsendi*, during 1991–1993. We made observations during winter (February 1991–1992), spring (June 1983 and 1991), summer (July–August 1991, 1992 and 1993) and fall (November–December 1991 and 1992), during a total of 189 days. Nearly all of our survey time (179 days) was on the east side of the island.

Observations of cetaceans were conducted: a) from the camp, located at "Corralitos", on the southeastern coast of the island (28°53′30″N), 30 m above sea level. Daily observations started at 0600 hr and ended at 2000 h; b) from the catwalk of Mexican Navy Coastguard boats (approx. 10 m above sea level) during the approach to or while leaving the island, and c) while conducting censuses of Guadalupe fur seals in the eastern side of the island (except in summer censuses, when the entire island was covered). These censuses were conducted in a 5–7 m fiberglass skiff with an observation height of ≤2 m, by two to four observers, along the shoreline at idle speed (2–3 knots).

Observer bias was relatively consistent because we collected the data on all census days. We estimated group size, and recorded ventilation times and general behavior of the cetaceans sighted. Results are given in averages ± standard deviation (S.D.). Eleven species of odontocetes and two species of mysticetes were observed.

Table 1. Relative abundance of cetaceans of Isla de Guadalupe in 1991–1993, expressed as number sighted per hour of effort (n = 101 observations).

	Spring	Summer	Fall	Winter	Total number (% of sightings)
Bottlenose dolphin *Tursiops truncatus*	7	62	2	2	72.28
Baird's beaked whale *Berardius bairdii*	1	4	2	1	7.92
Unidentified Bottlenose whale	—	5	—	—	4.95
Cuvier's beaked whale *Ziphius cavirostris*	1	1	—	—	1.98
Unidentified beaked whale	—	1	—	—	0.99
Sperm whale *Physeter catodon*	—	2	—	—	1.98
Dwarf sperm whale *Kogia spp.*	—	1	—	—	0.99
Common dolphin *Delphinus delphis*	1	—	—	1	1.98
Risso's dolphin *Grampus griseus*	—	—	—	1	0.99
Short-finned Pilot whale *Globicephala macrorhynchus*	—	—	1	1	1.98
Killer whales *Orcinus orca*	1	1	—	—	1.98
Blue whale *Balaenoptera musculus*	—	—	—	1	0.99
Fin whale *Balaenoptera physalus*	—	—	—	1	0.99
Total number of cetaceans	364	1241	84	76	1765
Hours of effort	180	840	240	160	1420
Number cetaceans/hour	2.02	1.5	0.4	0.5	1.24

Bottlenose dolphin, Tursiops truncatus

This was the most frequently observed cetacean year-round (Table 1). Group sizes were recorded almost daily, averaging 19 ± 12 individuals (range: 1–50 individuals, n = 73 schools). Bottlenose dolphins moved daily early in the morning (0600–0900 h), at a distance between 500 m and 3 km, parallel to the east coast heading north and returned moving south inshore in the evening (from 1600–2000 h). It was common to observe a very spread formation of dolphins moving slowly, apparently searching for prey. Upon finding a school of fish, aerial displays started, which congregated the dispersed dolphins and started the herding and encircling of fish schools. Immediately after this the dolphins chased the fish into the shallows and started feeding on them. The same behavior has been reported for *T. truncatus* from the Gulf of California (Gallo-Reynoso 1989). This behavior was observed when they were feeding on skipjack tuna (*Katsuwonus pelamis*) and yellowtail (*Seriola lalandei*). On other occasions, with the same behavior, they fed on chub mackerel (*Scomber japonicus*), Pacific golden-eyed tilefish (*Caulolatilus affinis*), red snapper (*Lutjanus peru*), and flying fish (*Cypselurus* sp.). On 18 February 1991, at 11:30, while traveling along the east coast of Isla de Guadalupe, we observed a group of 10 bottlenose dolphins that turned toward us, crossed our bow, moving rapidly between the four foot waves. The

dolphins appeared to be fleeing from a 4.0–5.0 m great white shark (*Carcharodon carcharias*) that was 30 m away and moving toward them. Interactions between bottlenose dolphins and great whites have been reported by Connor and Heithaus (1996). The dolphins escaped to the south moving fast and porposing out of the water.

Baird's beaked whale, Berardius bairdii

This was the second most observed odontocete in the study area. They were observed year-round in groups averaging 4 ± 0.9, individuals (range: 2–5, n = 8). These whales were identified by their size (9–13 m), their elongated, cylindrical beak and prominent melon. Calves (~5 m in length) were observed on three occasions, two in June and July 1991 and one in November 1992. A juvenile (~7 m in length) was observed in July 1991. These whales were on average sighted 3.2 ± 1.5 km offshore (range: 1–5.5 km). Dive times for these whales averaged 26.5 ± 8.5 min (range: 18–35, n = 8 dives). Twice on 8 July 1991, when the whales sounded, yellowfin tuna (*Thunnus albacares*) started to jump out of the water moving away from the whales.

Unidentified bottlenose whale

There were five observations of a large unidentified ziphid, similar to a bottlenose whale. They were observed only in the summers of 1992 and 1993. Gallo-Reynoso and Figueroa-Carranza (1995) described them as *Hyperoodon ampullatus*, but there is no authenticated record of this species in the eastern Pacific. In three occasions individuals of this species were breaching or partially breaching which facilitated their identification, showing a whitish head, buff colored body, squarish melon with short but well-defined beak, and falcate dorsal fin located two-thirds of body length all characteristics of *H. ampullatus* (Leatherwood and Reeves 1983). Size of breaching individuals was estimated at 7 m. Dive times averaged 17.6 ± 6.1 min (range: 10–25, n = 3 dives). These whales were diving over waters 810 ± 175 m (range: 600–1000, n = 5). During one observation, a partially breaching whale was accompanied by a school of 25 bottlenose dolphins, four of which were breaching with the whale for 10 min.

Cuvier's beaked whale, Ziphius cavirostris

They were observed on two occasions. These whales were identified by their brown coloration, white head with distinctive shape without a "beak", with many white scar lines on the head and dorsum, and a triangular dorsal fin, situated far in the back. A group of 7 individuals were observed in June 1991 at 300 m off the coast. The largest individual was compared to the skiff (7 m) and estimated to be 7.5 m. These whales were diving repeatedly in the same spot during four hours of observation. Diving times averaged 21 ± 10.2 min (range: 15–27, n = 16 divings). The group was accompanied by a school of 12 bottlenose dolphins which were also diving. The second observation (July of 1991), consisted of 5 individuals, 2 km offshore, slowly moving to the north while diving. The areas where these whales were diving averaged 565 ± 49.5 m in depth (range: 535–600, n = 2).

Unidentified beaked whale

Was observed in one occasion from a distance of 100 m. It had a non bulbous, whitish head, with a distinctive beak (shorter than in young *B. bairdii*). The dorsum was dark grayish-brown, with a few long white scars, and a broad falcate dorsal fin situated far in the back (Leatherwood et al. 1988). The size of the animal was about 5 m.

Sperm whale, Physeter catodon

Two observations on 28 July, 1993, 6.5 h apart (1233 and 1915 h) were possibly the same individual. The sperm whale was at an average distance of 4.4 ± 0.4 km (range: 4–4.8, n = 2), over waters more than 1000 m in depth. In the two observations the whale was moving to the north.

Dwarf or Pygmy sperm whale, Kogia spp

A group of 12 individuals were observed from the camp in August 8, 1993 at 1816 h, at about 3 km offshore. They were recognized by its small size, the lack of a conspicuous beak and their small but falcated dorsal fin found in the mid-dorsum. Dive times averaged 40 ± 15.7 min (range: 45–28, n = 4 divings). The group was slowly moving north against the current.

Common dolphin, Delphinus delphis

This species was recognized by its small size, the presence of a short beak and their characteristic clear coloration, compared to *D. capensis*. A large school of about 250 individuals was observed in June 1983, moving fast to the south. A second group, in February 1991, consisted of 15 individuals.

Risso's dolphin, Grampus griseus

A group of 12 individuals (including two calves) were observed in 6 February, 1992 at 12 km northeast of the island. The group surfaced from the depth and the younger individuals (judging by the size and darker coloration) rode the bow wave of the ship for two minutes, then returned to the group. Water depth was 2980 m.

Short-finned pilot whale, Globicephala macrorhynchus

This species was observed on two occasions, a group of six whales in February 1991, and a group of eight in November 1992, heading south.

Killer whale, Orcinus orca

Fishermen reported 10 whales (including a calf) hunting elephant seals at Playa Elefante (elephant seal beach) in June 1983. In August 1993, at 21:30 we registered the possible presence of this species as we heard from the camp at night that the whales were slapping their flukes vigorously very close to shore, their spouting was very strong. The fur seals were unusually silent, and a young elephant seal, shaking violently was hauling out in rocks where they don't normally climb. The slapping continued for several minutes, coming from at least four different locations. The slapping stopped when we searched with a light to identify the animals. Apparently the whales left after this and we did not hear them again. Although we never saw killer whales, the sound of their spouts and flukes slapping

in the surface and the behavior of the other marine mammals suggest their presence.

Blue whale, Balaenoptera musculus

We observed three individuals feeding close to Punta Sur (3 km), by doing sideways movements with their mouths open. They were slowly moving to the southwest at 1614 h on February 17, 1992.

Fin whale, Balaenoptera physalus

A large individual was observed 500 m offshore in February 1992. The whale was lunge-feeding and moving to the south.

The cetacean fauna at Isla de Guadalupe is dominated by squid eaters (61.5%, eight species): four species of beaked whales (Ziphiidae), two larger dolphins (Delphinidae: Globicephalinae), the sperm whale (Physeteridae) and a species of pygmy sperm whale (Kogiidae). There were also two fish and squid eating dolphins (Delphinidae) with 15.4%, and two zooplankton filtering whales (Balaenopteridae) with the 15.4%. One observed species has omnivorous habits (Delphinidae: Globicephalinae), with the 7.7%.

The composition of this cetacean fauna was somewhat different during the El Niño event of 1992, with a higher sea temperature and sea level (Fahrbach et al. 1991). Sea surface temperatures we measured during summer was 5°C higher in 1992, and 3°C higher in 1993 than the mean of 20°C during 1991 (Gallo-Reynoso 1994). Probably the absence of *Z. cavirostris* and the presence of an unknown bottlenosed beaked whale species, that was observed only in the summers of 1992 El Niño, and 1993 a post-El Niño year were related to the shift of squid species found during El Niño of 1992, in the diet of the Guadalupe fur seals. A greater proportion of southern squid species was found in the scats of these fur seals than in the previous year (Gallo-Reynoso 1994).

The few observations of blue and fin whales and the absence of other species of mysticetes may be related to the fact that the waters surrounding Isla de Guadalupe have a moderate primary production of ~36–84 gC/m^2yr according to Koblents-Mishke and coworkers (*in* Berger 1989).

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A General Allometric Model for Blade Production in *Zostera marina* L.

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Abstract.—We introduce a generalized allometric model to express leaf dry weight in terms of leaf width and size in *Zostera marina* L. A formal justification of the derived model is presented. For the statistical validation we used data collected on two well defined strata over a period of one year. A comparison of the results using an independent data set was also performed. Applications of the model to estimate average leaf production are illustrated as well.

The seagrass ecosystem such as *Thalassia testudinum* Baks ex König and *Zostera marina* L. have an important role in shallow tropical and temperate waters. These kinds of ecosystems are among the most productive marine systems. Consequently many attempts to predict their response to changes in the environment have been made. Most of the methods used to study marine phanerogams are expensive, time consuming, and require destructive techniques such as leaf marking (Sand-Jensen 1975; Jacobs 1979). Moreover it has been shown that excessive manipulation of raw material increases the error introduced in the data (Mandel 1964). Other techniques to measure seagrass production involve leaf cropping (McRoy and McMillan 1977) but such methods influence leaf growth and physiology (Hamburg and Homann 1986). In this paper we introduce a general allometric model which simplifies the estimation of blade production for *Zostera marina*. Our results could be applied to other marine phanerogams in a straightforward way.

The necessity to predict biomass and production for *Zostera marina* has stimulated the development of allometric models in productivity estimations. Patriquin (1973) used an allometric equation to predict leaf weight from leaf width for *Thalassia testudinum*. Jacobs (1979) gives a relationship between shoot length and density; McRoy (1970) relates leaf length and dry weight. Duarte (1991) presents an allometric study for marine phanerogams which considers the relationship between the sizes of different parts of a plant. Nevertheless, he does not include the variation of leaf dry weight in terms of length and width. Our allometric model permits the reduction of the problem of blade production estimation to the measuring of linear variates, particularly leaf length and width. For the calibration of the model presented here we used data collected in two well-defined strata over a period of one year. We obtained a remarkable consistency of the model with the measurements. An alternate validation used independent data sets.

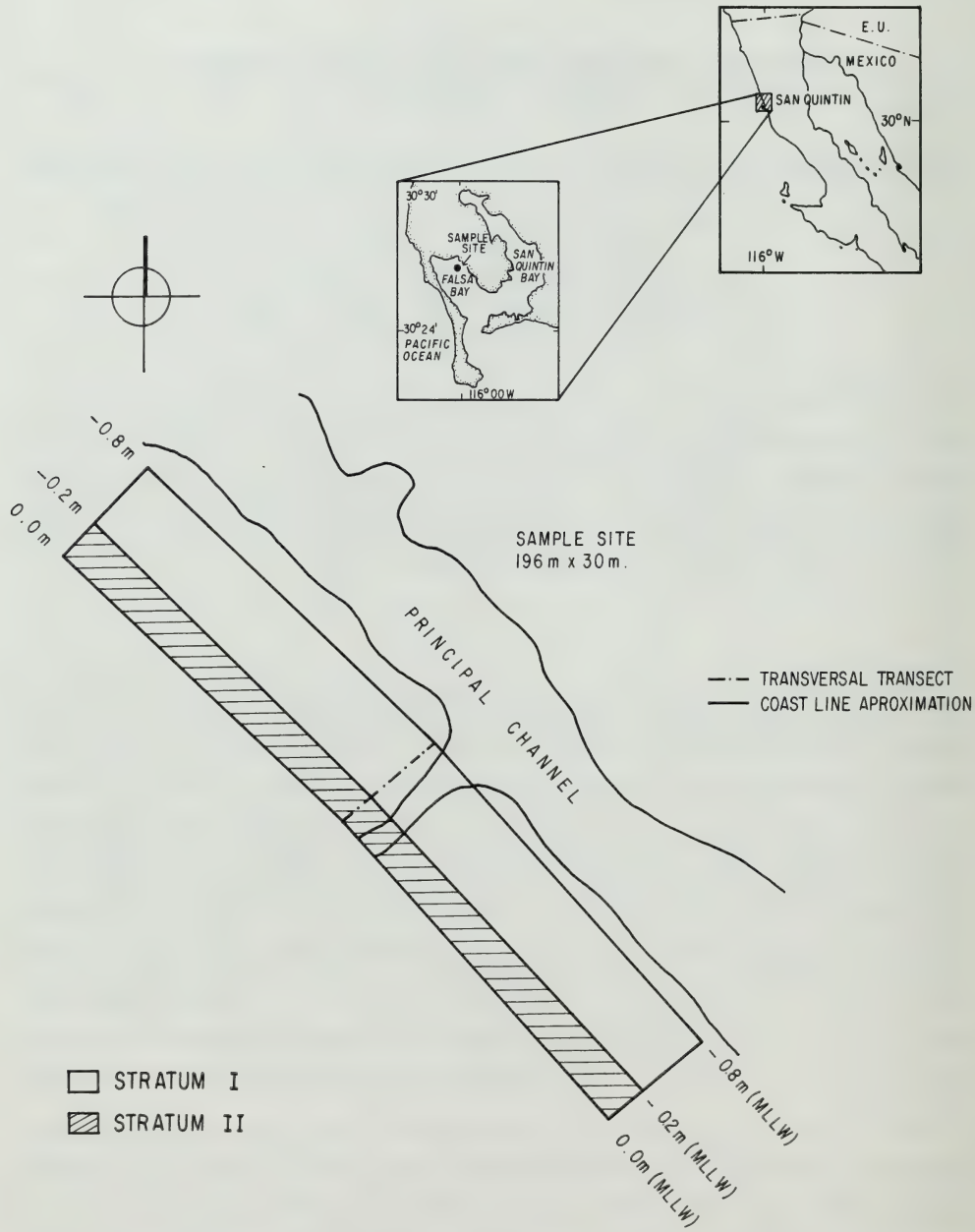

Fig. 1. Location of the study site. Two strata were sampled, one at −0.8 to −0.2 below (MLLW) (stratum I) and the other at −0.2 to 0 m below (MLLW) (stratum II).

(Solana et al. 1991). We also show the usefulness of the general allometric model to estimate the time variation of average leaf dry weight. This is obtained in terms of the allometric parameters and the leaf length and width averages. An example of the referred estimation is illustrated. It uses the allometric parameters obtained from our data and measurements of length and width obtained independently by Ibarra-Obando (1992).

Field, Laboratory, and Statistical Methods

The study was carried out in an area located in San Quintin Bay, Mexico, a coastal lagoon located in the Pacific Ocean waters of Baja California between 30°24′ and 30°30′N latitude and between 115°56′ and 116°01′W longitude. Ibarra-Obando and Huerta-Tamayo (1987) give a complete description of San Quintin Bay. The sampled site is a rectangular area 200 m by 30 m located in the arm of the bay (see Fig. 1). Ibarra-Obando and Huerta-Tamayo (1987) showed that there exist significant differences in the dynamics of *Zostera marina* L. between the intertidal zone and the transition intertidal zone. Hence we used a topographical study to determine two well-defined strata. Stratum I was from −0.2 m to −0.8 m below Mean Lower Low Water (MLLW) and stratum II from 0 m to −0.2 m below MLLW.

From November 1992 through November 1993 we sampled monthly eight quadrants of 20 cm by 20 cm in each stratum following a stratified random sampling (Wonnacott & Wonnacott 1984). We collected a total of 10,000 complete leaves from stratum I and 9000 from stratum II. Each sample was placed in individually labeled plastic bags and refrigerated until processed in the laboratory. To produce our data each shoot was cleaned with distilled water. Measurements of length and width were taken for each leaf, and then its dry weight was determined.

All the basic statistics and the fit of the model by means of non linear regression was obtained using the STATISTICA package (STATISTICA 1993). Finally we applied a goodness of fit test to corroborate that for both strata the regression equation used was consistent with the data with a probability of 0.95.

Theoretical Methods

The model presented here generalizes the equation introduced by Hamburg and Homann (1986). This relates leaf dry weight simultaneously with leaf size and width. In their formulation these authors considered that leaf dry weight depended linearly on leaf length and non linearly on width. Besides this restrictive assumption they did not provide a formal justification to their model. Our theoretical exploration shows that when length and width determine simultaneously the variation of leaf dry weight we must necessarily consider non linear dependencies in both variables.

At time t let $w(x,t)$ (measured in mg) be the weight and $l(x,t)$, $h(x,t)$ (both measured in mm) respectively the length and the width of a typical *Zostera marina* L. leaf collected at a position x of the two dimensional sampling space. Consider also that the measurement of the width is taken at the middle of the longitudinal size of each leaf. According with Batschelet (1975) we have the allometric relationships:

$$\frac{1}{w}\cdot\frac{\partial w}{\partial t} = \frac{k_1}{l}\cdot\frac{\partial l}{\partial t} \tag{1}$$

$$\frac{1}{h}\cdot\frac{\partial h}{\partial t} = \frac{k_2}{l}\cdot\frac{\partial l}{\partial t} \tag{2}$$

Where k_1 and k_2 are positive constants.

The allometric laws (1) and (2) permit us to obtain the direct dependency of

dry weight with respect to leaf length or width. The simultaneous dependency on both variables can be formally justified. To achieve this goal, we notice that according to the chain rule (Fulks 1978) we have;

$$\frac{\partial w}{\partial t} = \frac{\partial w}{\partial l}\cdot\frac{\partial l}{\partial t} + \frac{\partial w}{\partial h}\cdot\frac{\partial h}{\partial t}. \tag{3}$$

Combining equations (1), (2) and (3) we obtain,

$$\frac{k_1 w}{l}\cdot\frac{\partial l}{\partial t} = \frac{\partial w}{\partial l}\cdot\frac{\partial l}{\partial t} + \frac{\partial w}{\partial h}\cdot\frac{\partial l}{\partial t}\cdot\frac{k_2 h}{l}.$$

Simplifying we can establish the partial differential equation;

$$l\frac{\partial w}{\partial l} + k_2 h\frac{\partial w}{\partial h} = k_1 w. \tag{4}$$

In the appendix we have shown that a solution to equation (4) which satisfies the allometric relations (1) and (2) becomes,

$$w(x,t) = \kappa h(x,t)^{\alpha} l(x,t)^{\beta} \tag{5}$$

where κ, α and β are constants that can be obtained from the data.

The allometric model given by equation (5) can be used to estimate the dynamics for average leaf production using measurements of leaf size and width. Let us consider a set of leave samples. Suppose that the *mth* sample contains N_m complete leaves collected at a time t. Then for the *ith* leaf in that sample equation (5) gives

$$W_{mi}(x_{mi},t) = \kappa h_{mi}(x_{mi},t)^{\alpha} l_{mi}(x_{mi},t)^{\beta} \tag{6}$$

where $W_{mi}(x_{mi},t)$, $h_{mi}(x_{mi},t)$, and $l_{mi}(x_{mi},t)$ are respectively the dry weight, the width and length of the considered leaf. In our notation, the sub-index *mi* identifies a leaf collected at a position x_{mi} and belonging to the *mth* sample for $1 \leq i \leq N_m$. Taking logarithms in (6) and averaging we have

$$\frac{1}{N_m}\sum_{i=1}^{N_m}(\ln w_{mi}(x_{mi}, t)) = \ln \kappa + \frac{\alpha}{N_m}\sum_{i=1}^{N_m}\ln h_{mi}(x_{mi}, t) + \frac{\beta}{N_m}\sum_{i=1}^{N_m}\ln l_{mi}(x_{mi}, t) \tag{7}$$

The left hand side of equation (7) gives the natural logarithm of the geometric mean of the set of N_m dry weight values in the sample. This equation also permits the exploration of the validity of equation (5) for different data sets. It is worth to point out that the variability observed in the measurements makes the geometric mean of dry weight a better estimator of central tendency for leaf dry weight. On the other hand the use of logarithms in equation (7) will avoid the vanishing effect associated to the large product of small numbers required to obtain the referred mean.

Results

Using the collected data, we tested the model given by equation (5). We obtained very similar results for both strata (see Table 1). No spatial dependencies for the allometric parameters κ, α and β along the strata where detected. For stratum I and stratum II the coefficients of determination were 0.91 and 0.87

Table 1. Estimations for both strata of the fitted parameters and their respective standard errors.

	Stratum I	Stratum II	Std. error Stratum I	Std. error Stratum II
κ	0.000005	0.000015	0.04($p < 0$)	0.03 ($p < 0.0$)
α	1.09	1.3	0.01 ($p < 0.05$)	0.01 ($p < 0.0$)
β	0.469	0.45	0.04 ($p < 0.05$)	0.03 ($p < 0.0$)

respectively. The standard error for the estimate was 0.43 for stratum I and 0.55 for stratum II. For both cases the parameters found in the regression have very small standard errors and very significant p-values (see Table 1). The residual analysis for both strata gave no indication of lack of fit of the model.

Plots of the predicted and observed values of leaf dry weight are presented for each stratum to provide a visual interpretation of the adequacy of the fit (see Fig. 2). Finally a lack of fit F-test was applied to data in both strata. We obtained significant evidence that the expected value of the dependent variable w is indeed represented by means of the allometric equation (5) with a probability of 0.95.

Using data collected on a preliminary sampling, Solana et al. (1991) found similar values for the parameters κ, α and β. This was corroborated using a Student-t test at a 95% confidence level. As a conclusion equation (5) gives the correct allometric relationship for the involved variables in our study site.

An application of the present model was performed. Using the values of the parameters κ, α and β corresponding to our data, we simulated the behavior of the average mean dry weight as given by equation (7). For that purpose we used an independent data set for leaf length and width collected by Ibarra-Obando (1992) in the same MLLW level of stratum I. Fig. (3) shows the temporal variation of the average dry weight obtained directly from our data and the predicted by quation (7) for the Ibarra-Obando (op. cit.) data set. Using analysis of variance and a LSD (Least significant difference) test, we found no significant differences between both means. This shows that the sample paths shown in Fig. (3) are both generated by the same stochastic process. This also implies the consistency of the considered allometric relationship.

Discussion

The characterization of productivity for the eelgrass *Zostera marina* both under laboratory and in situ conditions has been relevant in the study of the ecology of the seagrass ecosystem. The advantages of allometric relationships in these studies are pointed out by several authors e.g., (Jacobs 1979, McRoy 1970, Duarte 1991, Patriquin 1973, Hamburg and Homann 1986). An allometric description of dry weight in terms of direct in situ measurements could avoid tedious laboratory processing and destructive sampling. The model we tested here permits the expression of leaf dry weight in terms of leaf length and width through a simple equation whose parameters are easily obtained using available nonlinear regression methods. Although a form close to the proposed model was introduced by Hamburg and Homann (1986) no formal justification was provided. Furthermore the model proposed by these authors considers linear dependence of dry weight with respect to leaf length. That model fails to provide the generality of the allometric equations (1) and (2). On the other hand, as it is shown in the appendix,

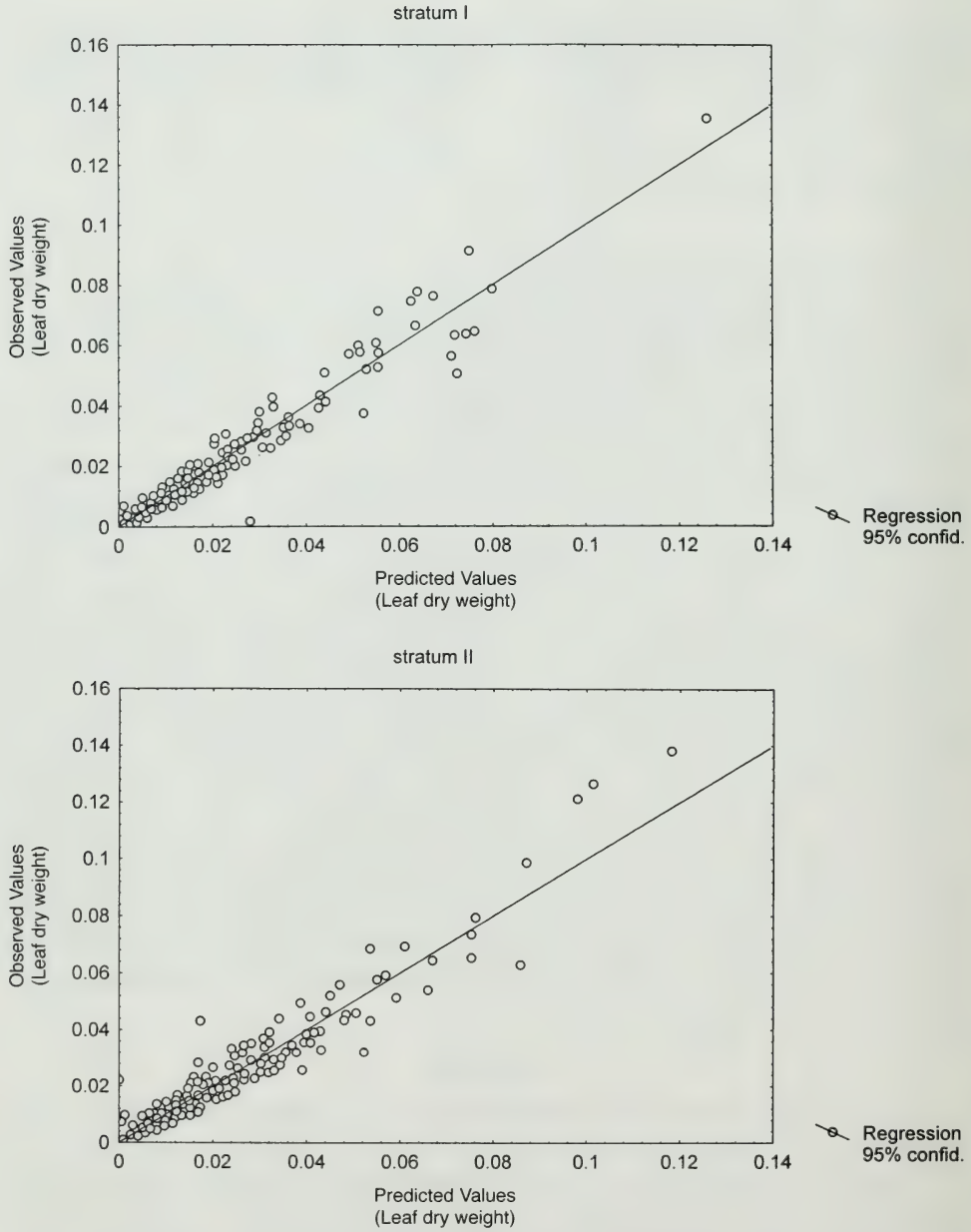

Fig. 2. Predicted vs. observed values of leaf dry weight predicted by equation (5) in terms of leaf length and width. a) Stratum I. b) Stratum II. To produce these plots we selected a random sample of 1000 leaves.

the model given by equation (5) can be justified using the results in the theory of first order partial differential equations. We conclude that an allometric relation in the form proposed here must necessarily be considered in order to express leaf dry weight in terms of length and width measurements.

The model that we present here provides a simple procedure to identify the

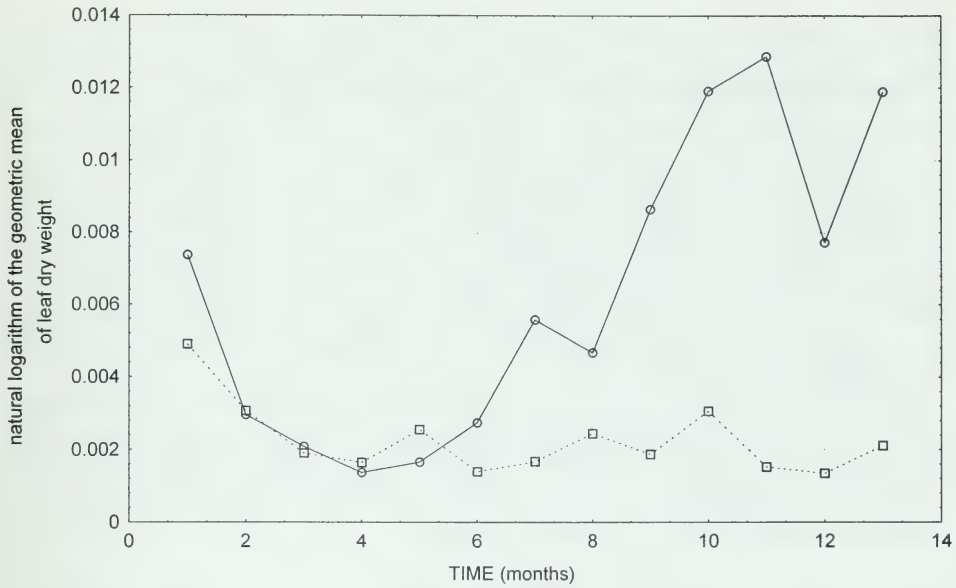

Fig. 3. Variation over time natural logarithm of the geometric mean of leaf dry weights. The continuous line corresponds to our data. The dashed line represents the simulation of the mean leaf dry weight predicted by equation (7) using data on leaf length and width obtained by Ibarra-Obando (1992) and the allometric scaling parameters κ, α and β found in the present study.

allometric scaling factors for the considered variables. The high determination coefficient obtained for the data sets analyzed in this study corroborate the claim that our model is consistent with these observations. Our model was also tested against independent data sets. In a preliminary application of our model using only 21 shoots in a single sample, Solana et al. (1991) found similar values for the allometric parameters. A Student-t test gave no indication of statistical differences. Hence we can expect that the values obtained for the allometric parameters κ, α and β will not depend on the particular data set considered. As a conclusion the model given by equation (5) identifies unambiguously the allometric linkage which relates the variation of the leaf dry weight as a function of leaf length and width for *Zostera marina* L. in our study site. When we used the values of parameters κ, α and β found with our data to obtain by means of equation (7) the dry weight corresponding to data on length and width (Ibarra-Obando 1992) we observed some deviations with respect to the corresponding values measured in our study. As we have pointed out, these characterizations of the temporal variation for the leaf mean dry weight portrayed in Fig. (3) correspond to sample paths of the underlying stochastic process. Nevertheless these deviations could be explained by the occurrence of a strong "El Niño Southern Oscillation" (ENSO) event which took place from June 1986 to January 1988; that is just before and during the year where the data were taken (Climate Diagnostic Bulletin 1996). Solana et al. (1996) found that temperature is the most significant variable in the determination of leaf size dynamics in our study site. In the same study, dissolved nutrients were also found to be a determinant. The ENSO event was reported to induce an increase of water temperature and a re-

duction of dissolved nutrients in San Quintin Bay (Silva-Cota and Alvarez-Borrego 1988). By virtue of the tolerance law, the rise in water temperature could have produced sub-optimal leaf growth rates. High temperature stress has been claimed to induce a deleterious effect for *Zostera marina* (Rasmusen 1977). It has also been reported that a sizeable increment in temperature reduced shoot abundance and a change in the seasonal pattern of abundance of *Z. marina* in Chesapeake Bay (Penhale 1977; Wetzel and Penhale 1983; Evans et al. 1986). In our study site the reduction of nutrients could have also contributed to the predicted reduction of average leaf dry weight. The conjunction of high temperature-stress and a reduction in dissolved nutrient availability could have created a delayed response characterized by a smaller leaf production which was observable in summer of 1987.

Given the values of the allometric parameters equation (7) becomes an adequate tool to estimate leaf production in *Zostera marina* L. (see Fig. 3). We claim that our model is a general tool which could be straightforwardly applied in other studies. This will simplify biomass estimations, eliminating tedious laboratory processing while avoiding destructive sampling.

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Appendix

According to theorem 2.1 in Zachmanoglou and Thoe (1976) (pages 60–61), the solution $w = f(h,l)$ of equation (5) is given implicitly by the relation:

$$F(u_1(h,l,w),u_2(h,l,w)\ ) = 0 \tag{A1}$$

Where F is a function of class C^1 and u_1, u_2 are two functionally independent solutions of the auxiliary system:

$$\frac{dl}{l} = \frac{dh}{k_2 h} = \frac{dw}{k_1 w} \tag{A2}$$

From the system (A2) we can obtain by direct integration

$$\frac{l}{h^{\alpha}} = \frac{l_0}{h_0^{\alpha}} \tag{A3}$$

$$\frac{l^{\delta}}{w} = \frac{l_0^{\delta}}{w_0} \tag{A4}$$

Where w_0, l_0 and h_0 are respectively the dry weight, the length and width of a leaf at the beginning of the growing process and α and δ are constants defined in terms of the allometric scaling factors k_1 and k_2 (see equation (1) and (2)) trough the relationships

$$\alpha = \left(\frac{1}{k_2}\right) \tag{A5}$$

$$\delta = k_1 \tag{A6}$$

From equations (A3) and (A4) we see that the functions u_1 and u_2 defined according to

$$u_1(h,\ l,\ w) = \frac{w}{l^{\delta}} \tag{A7}$$

$$u_2(h,\ l,\ w) = \frac{h^{\alpha}}{l} \tag{A8}$$

satisfy

$$grad(u_1) \times grad(u_2) \neq 0$$

in the region $l > 0$, $h > 0$ and $w > 0$. Then in general $u_1\ (h,\ l,\ w) = c_1$ and $u_2\ (h,\ l,\ w) = c_2$ where c_1 and c_2 are constants, define two functionally independent solutions of the auxiliary

system (A2). Hence for u_1 and u_2 as given by equations (A7) and (A8) the implicit relation (A1) gives the general integral to p.d.e. (4).

From equations (A7) and (A8) it is easily seen that

$$\frac{1}{h^{\alpha}} = \frac{l^{\delta}}{w}\left(\frac{w_0}{l_0^{\delta-1}h_0}\right) \tag{A9}$$

hence for u_1 and u_2 as defined above we have

$$u_1 - cu_2 = 0 \tag{A10}$$

Where c is a constant that can be identified using equation (A9). Consequently equations (A1), (A10), the choosing

$$F(u_1, u_2) = u_1 - cu_2$$

and the implicit relation (A1) permit to conclude that the function

$$w = Kh^{\alpha}l^{\beta}$$

Where $\beta = \delta - 1$ is a solution to equation (4) which also satisfies the allometric equations (1) and (2).

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McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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Range Extensions of Ten Species of Bats in California

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Abstract.—Ten rare or uncommon species were among some 22,000 bats identified after being tested for rabies in California: *Macrotus californicus, Choeronycteris mexicana, Leptonycteris curasoae, Myotis velifer, Lasionycteris noctivagans, Lasiurus blossevillii, Lasiurus xanthinus, Nyctinomops femorosaccus, Nyctinomops macrotis,* and *Eumops perotis*. Numerous geographic range extensions were among 194 new localities reported. Perceived range extensions of southerly species may be due to either increased sampling, global warming or other factors. Identification by professional taxonomists of host animals tested for pathogens is encouraged to save valuable data and as prerequisite to disease problem comprehension and resolution.

New geographic range records and associated data have resulted from the identification of more than 22,000 bats tested for rabies in California. Distributional highlights of 425 bats of ten generally rare or uncommon species, nearly all supported by preserved specimens, are presented here, whereas additional distributional, population, ecological, and rabies epidemiological studies of these and common species are in progress.

Methods

The author periodically identified bats tested for rabies in California subsequent to his first bat rabies survey in the state in 1954 (Enright et al. 1955), but it was not until 1977 that he did so regularly, if on a voluntary basis. Counties that could cooperate shipped the carcasses of bats they had tested to the author, who was employed at the California Department of Health Services in Berkeley.

Other workers participated in identifications in early years. Keith F. Murray made several determinations cited in Constantine et al. (1979). Beginning in 1973 and ending in 1981, former Los Angeles Department of Health Services biologist Loran M. Whitelock, who earlier had worked on bats with the author, performed bat identifications for that county. Personnel took relevant health precautions (Johnson 1979: Constantine 1988), including preexposure rabies immunizations.

Nearly all carcasses were damaged and decomposed when received, and the cranium had been opened to remove the brain, destroying key characters needed to differentiate some species. Most rare or uncommon bats were salvaged as skeletons or in fluid preservatives, and a few were prepared by the author as study skins, despite some hair slippage.

Measurements are presented to support certain critical identifications. Different measurement methods were sometimes used for different species in order to match techniques used by authors of relevant published studies and thus facilitate comparisons by the reader. Most external measurements were made with a rule. Forearm, wing digit, and cranial measurements were made with dial calipers.

Most new locality records are merely listed, in accordance with the limited purpose of this report, relevant details being reserved for other reports, but the more unexpected records are given in detail. Plant communities, cited in reference to especially unusual locality records to reflect ecological parameters, are from Kuchler (1977).

Maps bear a single symbol for each new (closed circle) or previously published (open circle) locality. Symbols do not reflect the numbers of reports or specimens. Museum catalog numbers and other details are generally given only for specimens that represent peripheral range extensions, although a few of these bats have not yet been cataloged. Recipient museums are the Museum of Vertebrate Zoology, University of California, Berkeley (MVZ) and the Natural History Museum of Los Angeles County (LACM).

Results

California leaf-nosed bat
Macrotus californicus Baird 1858

This insectivorous species has been reported from northern Sinaloa and southwestern Chihuahua, Mexico northward through Sonora and Baja California to southern California, extreme southern Nevada, and southern Arizona; an apparently disjunct population has been reported in Tamaulipas, Mexico (Koopman, 1993). The species is included herein primarily to report recent observations at reported and unreported westernmost stations of known occurrence.

Howell (1920b), referring to this species in a cave (see photograph in Howell's paper), said to be 2 mi N of Owensmouth, Los Angeles Co., reported six of the bats present on 6 April, none on 4 June, and about thirty on 14 December (years not given). Owensmouth has been renamed Canoga Park. The cave, about 24 m deep and 9 m high in calcareous conglomerate, was called Vanowen Bat Cave by Halliday (1962) after the author took him there. It was found to be in the first canyon south of Bell Canyon, about 6.6 km W of Canoga Park and just inside Ventura Co. some 0.97 km W of the present end of Vanowen Street at Sunset Ridge Court. On 30 January 1949, I observed three *Macrotus* on the cave ceiling. Identified by their large ears, nose leaves, and "twirling" when hanging by one foot to watch the observer, they were not disturbed further. No bats were seen in the cave on subsequent visits made February 1953, 4 July 1989, and 27 April 1990.

A second cave, this one in Los Angeles Co. about 10.31 km NNE of the first cave and about 3.32 km NNW of Chatsworth, was found by Thomas Cade and Gary Casey to contain a small group of these bats on 8 May 1947, when six were collected, prepared as skins, and given to the LACM. I joined them on a visit to the cave later that month, when several *Macrotus* skeletons were found on the cave floor. Mark Ryan collected a bat at this cave 15 June 1950 (MVZ 113637). The cave was a dugout under several large adjacent boulders on an extensive boulder-strewn property known as the Iverson Ranch. The area has since been bisected by a freeway and subdivided for housing, with much ground surface distortion. A search for the cave by the author and Kenneth E. Stager in April 1990 was unsuccessful.

Only four *Macrotus* are known to have been submitted for rabies testing in

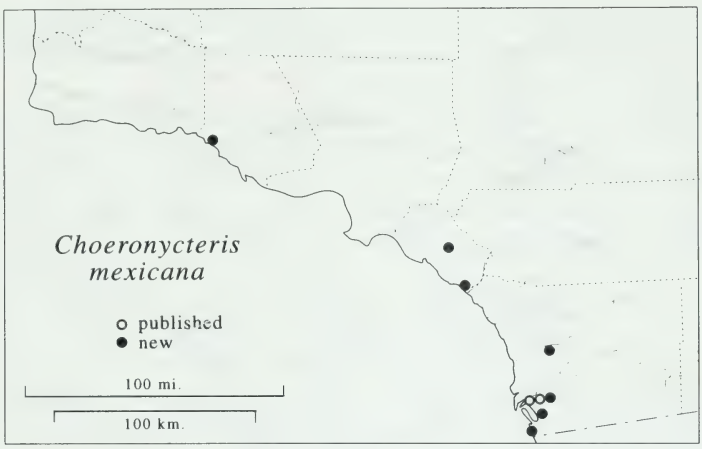

Fig. 1. Known distribution of the Mexican long-tongued bat, *Choeronycteris mexicana*, in California.

California, as expected for a species that prefers living far from human habitat. They were from within the known range in Imperial, San Bernardino, and San Diego counties.

Mexican long-tongued bat
Choeronycteris mexicana Tschudi 1844

This nectar, pollen, and fruit-eating bat has been reported from El Salvador and Honduras (Arroyo-Cabrales et al. 1987) northward through Mexico, including Baja California, to San Diego, California (Olson 1947), southern Nevada (Constantine 1987), southern Arizona (Hoffmeister 1986), southwestern New Mexico (Findley et al. 1975), and extreme southern Texas (LaVal and Shifflett 1971).

The first observations of this species in California were made September to December 1946, during an "invasion" by the species, in San Diego, San Diego Co. Fifty of the bats were collected, usually as individuals found hanging in dimly lit sites about buildings, but as many as 40 to 50 were seen at one place and time, with probably 75 total bats being detected (Olson 1947; Huey 1954b). Bond (1977) mentioned that subsequent San Diego specimens were obtained in October of 1947 and 1963 and in December 1947. Banks and Parrish (1965) reported another specimen taken 15 October 1963 from Lemon Grove, at the eastern edge of San Diego.

I have received 15 additional bats of this species: 10 from five localities in San Diego Co., three from at least two localities in Orange Co., one from Los Angeles Co., and one from Ventura Co. Unfortunately, labels came off individual containers within two frozen shipments, so data on two of these bats (one each from Los Angeles and Orange counties) were lost (Fig. 1, Appendix).

The San Diego Co. bats do not represent remarkable range extensions. The first Orange Co. bat, a female (MVZ 181846), was taken at an unknown place and date between 1976 and 1978. The second, a male (MVZ 186389), was taken at San Clemente 28 September 1993. The third, a male (LACM 94031), was found at Tustin on 24 November 1995. The Los Angeles Co. bat, a female (MVZ

181845), was taken at an unknown locality and date between July and December 1988. The Ventura Co. bat, a male (LACM 94032), was found 15 November 1994 at Ventura, 260 km NW of San Diego.

This species, one of three leaf-nosed bats now known in California, is readily differentiated from the other two. *Macrotus* has huge ears compared to the relatively short ears of *Choeronycteris* and *Leptonycteris*. The latter lacks an evident tail, whereas the short and exsert tail of *Choeronycteris* arises from the dorsal surface of the interfemoral membrane near its base.

Southern long-nosed bat
Leptonycteris curasoae yerbabuenae
Martinez and Villa-R. 1940

These nectar and pollen eating bats are reported to appear in southern Arizona in spring, produce offspring in colonies within caves and mine tunnels, and disappear in fall, evidently returning south into Mexico (Hayward and Cockrum 1971; Hoffmeister 1986). Arita and Humphrey (1988) considered *L. curasoae* to be divisable into two subspecies: (1) *L. c. verbabuenae*, distributed from southern Arizona, New Mexico, and Tamaulipas, Mexico southward to Guatemala and El Salvador, and (2) *L. c. curasoae*, thus far known as a disjunct population in northern Colombia and Venezuela and nearby Caribbean islands. The species is reported herein for the first time from California, where two bats were found, each in a different county in the southern part of the state.

The first bat was found in suburban Yucaipa, 799 m elev., San Bernardino Co., formerly characterized by coastal sagebrush, adjacent to chapparal-covered hills. At about 1100 h PDT, 3 October 1993, a male bat (MVZ 186390) was inadvertently flushed from a shaded site behind a meter-high bush growing next to the outer side of a residence chimney, which was flush against the south side of a one-story house. The bat flew about 4.6 m through the back door and into the shade of a screened carport-patio, where it was captured. After brain removal, the carcass was frozen and sent to the author four months later, when it was made into a study skin with skeleton, and other tissues were saved. Dehydration precluded getting reliable ear and weight measurements.

The second bat, a male (LACM 94033), was found in urban Oceanside, 14 m elev., San Diego Co., an area of former coastal sagebrush adjacent to chapparal and southern oak forest. The bat was observed at 900 h PDT 18 October 1996 hanging outside under a canopy over the front door of a business concern. The frozen carcass was received by the author four months later, when it was prepared as a study skin and skeleton. The bat had considerable deposits of subcutaneous fat throughout but especially in the neck, interscapular, and leg base areas.

The bats were identified as *L. curasoae* and not *Leptonycteris nivalis* by comparing them with skins and literature. Measurements were made using methods described by Arita and Humphrey (1988), except bilateral measurements were taken, where applicable, and averaged. The hair coat was typically short and dense, and the hair fringe on the border of the uropatagium was inconspicuous. The presphenoid ridge was prominent and rounded. Recoverable measurements (Table 1) were consistent with those published for samples of bats designated *L. c. verbabuanae* from Morelos and Colima, Mexico by Arita and Humphrey (1988), from Baja California Sur, Mexico (as *L. sanborni*) by Woloszyn and Wo-

Table 1. *Leptonycteris curasoae*: measurements (mm) and weight (g).*

Measurement	Yucaipa, San Bernardino Co 3-X-1993	Oceanside San Diego Co 18-X-1996
Total length	70	81
Length of foot	14.4	14.0
Length of ear from notch		17.0
Length of folded forearm	53.70	52.95
Length of 3rd digit	99.45	99.15
Length of 3rd metacarpal	49.05	49.65
Length of 1st phalanx of 3rd digit	14.58	13.75
Length of 2nd phalanx of 3rd digit	23.47	23.75
Length of 3rd phalanx and cartilage of 3rd digit	12.35	12.00
Condylobasal length	25.80	26.17
Greatest cranial length excluding incisors	26.35	
Zygomatic width	10.30	10.78
Least interorbital width	4.35	4.40
Greatest width of braincase	10.09	9.98
Greatest width at mastoids	10.80	10.64
Width of rostrum at last maxillary molars	6.60	6.40
Length of palate excluding spine	14.14	14.18
Length of maxillary tooth row excluding incisors	9.00	8.95
Length of mandible	17.98	18.10
Length of mandibular tooth row excluding incisors	9.48	9.27
Weight (less brain)		22.2

* Methods are from Arita and Humphrey, 1988.

loszyn (1982), and from Arizona (as *L. nivalis sanborni* and later as *L. sanborni*) by Hoffmeister (1957, 1986).

The present known distribution of *L. c. verbabuenae* in the United States and northwestern Mexico is indicated in Fig. 2.

Yucaipa, the new northernmost locality where the species is known, is 463 km west and slightly north of the previous northernmost locality at Glendale, Maricopa Co., Arizona (Constantine 1966), 420 km NNW of the previous westernmost locality in the United States at Agua Dulce Mountains, Pima Co., Arizona (Cockrum and Petryszyn 1991), and 823 km NNW of the northernmost Baja California Sur, Mexico, locality at Santa Rosalia (Arita and Humphrey 1988). Oceanside is 98 km SSW of Yucaipa.

Cave myotis
Myotis velifer velifer (J. A. Allen 1890)

This insectivorous species is known to occur from the southeastern California and Nevada borders at the Colorado River to Kansas and southward through mainland Mexico and Guatemala to El Salvador and Honduras (Hayward 1970; Helebuyck et al. 1985). The subspecies *M. v. velifer* reportedly occupies the western and southern parts of the range. Hayward (1970) concluded that the smaller bat of the southern end of Baja California Sur, Mexico, classified as *M. v. peninsularis* by Miller and Allen (1928), is a separate sibling species, *M. peninsularis*, as originally determined by Miller (1898).

Found during warm months in California only near the Colorado River, aggre-

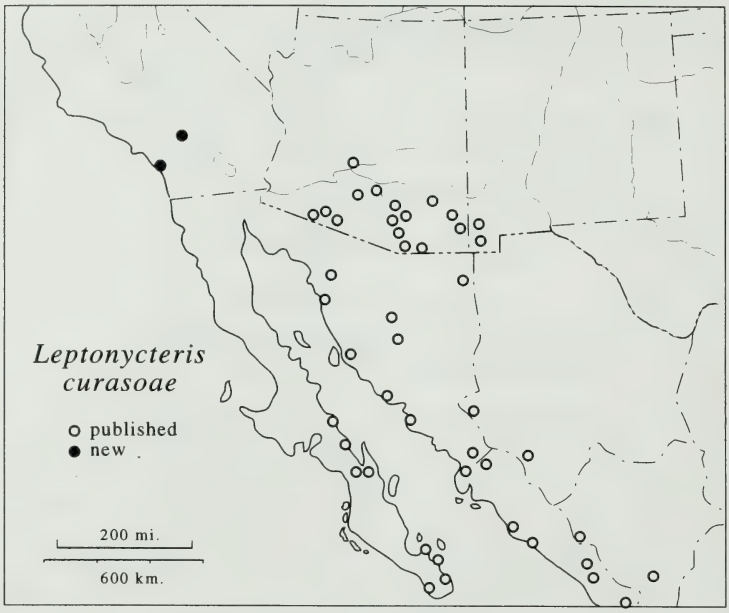

Fig. 2. Known distribution of the southern long-nosed bat, *Leptonycteris curasoae yerbabuenae*, in the southwestern United States and northwestern Mexico. From Arita and Humphrey (1988), Cockrum and Petryszyn (1991), Hoffmeister (1986), and the present study.

gations of this presumably migratory subspecies previously were common in abandoned mine tunnels, where its numbers have been drastically reduced. Three bats of this species are reported herein from Los Angeles Co., a surprising distance westward from the former westernmost known boundary of the species.

The first bat, a female (MVZ 186397), was captured after it flew through a door into a house during daytime 28 September 1992 at Florence, 49 m elev., an urban area originally of coastal sagebrush. The scalped carcass was received by the author the next month when it was salvaged as a skin and skeleton, although it was decomposed with extensive hair slippage.

The second bat, a male (MVZ 186398), was found alive during daylight the morning of 28 November 1994 clinging to an overhang above a door at Valencia, 303 m elev., in a parklike suburban setting with adjacent chapparal and riparian vegetation. The scalped, decomposed and somewhat dessicated carcass was sent to the author some six months later when it was salvaged as a skin, legs and tail vertebrae contorted within the shriveled uropatagium, and skeleton with skull fragments.

The third bat, a male (LACM 94035), whose canines were shortened by wear, was captured about 1900 h PST 27 March 1997 while hanging in a covered entryway outside the front door of a residence at Lancaster, 718 m elev. Areas representing three plant communities meet in the vicinity: Joshua tree scrub, Mojave creosote bush, and desert saltbush. I received the partially decomposed carcass the following month and salvaged it as a skin and skeleton.

Some external and recoverable cranial measurements of the three bats are pre-

Table 2. *Myotis velifer* from Los Angeles Co: measurements (mm) and weight (g).*

Measurement	Florence 23-IX- 1992	Valencia 28-XI-1994	Lancaster 3-XII- 1996
Total length	95	98	95
Length of tail	41	43	42
Length of foot	9.0	9.7	10.0
Length of ear from notch		13.5	14.5
Length of forearm	42.75	44.05	42.40
Occipitonasal length	15.70		15.86
Condyle-premaxillae length (C)	15.05		14.94
Cranium breadth	7.55	8.10	7.78
Mastoid breadth	7.85		8.08
Rostrum breadth (H)	4.53	4.21	4.60
Least interorbital breadth	3.55	4.05	3.65
Braincase depth (H)	5.82		6.12
Maxillary tooth row length	6.33	6.18	6.32
Length of mandible (C)	12.17	11.99	12.29
Mandibular tooth row length (C)	6.71	6.66	6.67
Weight (less brain)			6.9

* Methods are from Hayward, 1970, who cited Cockrum, 1955 (C), from Hoffmeister, 1986 (H), or from both where identical methods were used.

sented in Table 2, and localities of collection are indicated in Fig. 3 and the appendix.

The measurements of the three bats are consistent with those given by Grinnell (1918), Miller and Allen (1928), Stager (1939), Vaughan (1954), Hayward (1970), and Hoffmeister (1986), although there are some differences between these authors possibly referable to methods or specimen sexes and ages.

The long forearms of these three bats separate them from all other members

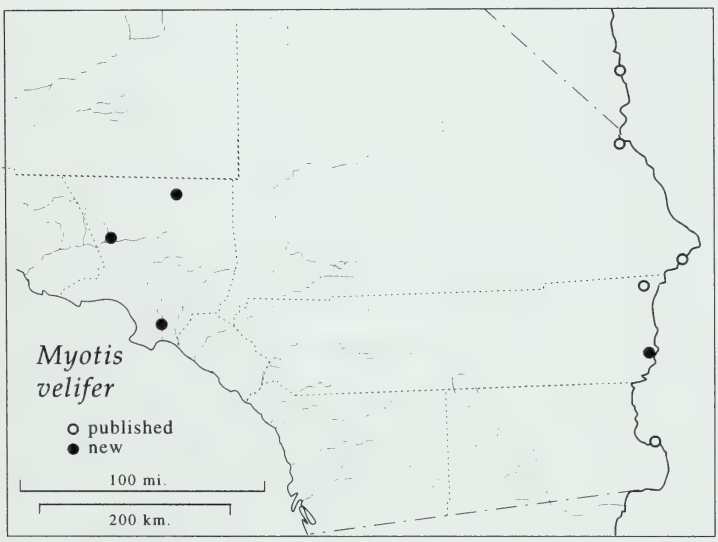

Fig. 3. Known distribution of the cave myotis, *Myotis velifer velifer*, in California and adjacent border areas.

of the genus known from the United States except *M. volans*, *M. thysanodes*, and the southeastern *M. grisescens*. However, like *velifer* they lack the rounded ears, furred basal wing membranes, and keeled calcar of *volans*, the fringed uropatagium and larger ears of *thysanodes*, and the unicolored dorsal hairs and tarsal wing attachment of *grisescens*.

Valencia, Los Angeles Co., is now the westernmost known locality for this species and is 377 to 482 km W of the previously reported westernmost localities at or near the Colorado River as follows:

Jackass Flats, Clark Co., Nevada (Cockrum and Musgrove 1964)
Needles, San Bernardino Co., California (Grinnell 1918)
Parker, La Paz Co., Arizona (Hoffmeister 1986)
Riverside Mountains, Riverside Co., California (Stager 1939)
Blythe, Riverside Co., California (LACM 13626)
Picacho, Yuma Co., Arizona (Hoffmeister 1986)

Valencia is distant from the other two Los Angeles Co. localities as follows: 52 km WSW of Lancaster, and 62 km NNW of Florence.

The three cave bats from Los Angeles Co. are the only bats of that species known to have been tested for rabies in California.

Silver-haired bat
Lasionycteris noctivagans (Le Conte 1831)

This insectivorous and presumed migrant has been reported from forested areas throughout North America from southeastern Alaska across the southern half of Canada and southward to or near the southern border of the United States excluding Florida, southwestern Arizona, and southern California (Hall 1981; Kunz 1982). Thus far, only one bat has been reported from Mexico, in Tamaulipas, south of Texas (Yates et al. 1976). The species is also known to occur during spring and fall in Bermuda, evidently as wind-blown migrants from the east coast of North America (Van Gelder and Wingate 1961).

The distribution of this species in California is generally depicted on maps to include and extend from the northern third of the state southward along coastal mountains to Pacific Grove, Monterey Co. (Grinnell 1918) and, leaving the San Joaquin Valley blank, southward through the Sierra Nevada Mountains and, in the eastern part of the state, to Death Valley National Park (Grinnell 1937; Bradley and Deacon 1971). However, Bond (1977) reported a bat much farther south in eastern San Diego County.

I have identified numerous bats of this species from nearly all counties in the northern two-thirds of the state, including the counties of Monterey, Kings, Tulare, and Inyo northward. Unfortunately, relatively few bats of any species were received during much of the period under consideration from the counties of San Luis Obispo, Kern, Santa Barbara, and Imperial, so the absence of silver-haired bats from those counties is of little significance. However, 23 of the bats were received from 15 new localities in the southern Californian counties of Los Angeles, San Bernardino, and San Diego during 1973–1997 (Fig. 4, Appendix). Of the 23 bats from southern California, seven (identified by L. M. Whitelock) were discarded before I was able to review and salvage specimens. Thus, voucher specimens were lost for the following localities in Los Angeles Co.: Bellflower, Lakewood, and Torrance.

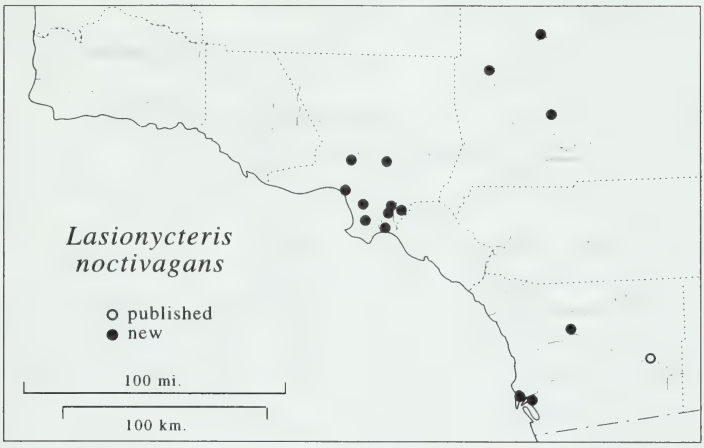

Fig. 4. Known distribution of the silver-haired bat, *Lasionycteris noctivagans*, in southern California.

The southernmost California locality for this species on the Pacific coast is San Diego, represented by a male (MVZ 181863) taken 15 February 1978. San Diego is 615 km SE of the previously published southernmost Pacific coastal locality at Pacific Grove (Grinnell 1918) and 84 km WSW of the inland collection site at Agua Caliente Springs in eastern San Diego Co. (Bond 1977).

Western red bat
Lasiurus blossevillii frantzii (Peters 1871)

This insectivorous, foliage-dwelling, migratory bat, recently regarded as taxonomically separate from the eastern red bat, *L. borealis* (Baker et al. 1988; Morales and Bickham 1995), has been reported from southern British Columbia, Canada, Utah, and western Texas southward through the western United States, Baja California, mainland Mexico, Nicaragua, and south into South America (Hall 1981; Shump and Shump 1982; Eisenberg 1989; Redford and Eisenberg 1992).

This species generally occurs in California's central valley, foothills, and in similar areas of tree growth in southern California, preferring the dense foliage of trees for shelter, presumably avoiding tree-deficient deserts. Range maps often depict continuity of distribution through areas of unknown occurrence, although supportive data are unavailable. Such is true of this species in reference to Californian deserts. That limitation may be less misleading in reference to migrants like the red bat that may seasonally or periodically migrate or stray into or through these deserts. The following report may represent such an occurrence.

On 21 October 1991, a female western red bat was found crawling on the ground at the Park Village government housing area near Furnace Creek Ranch, Death Valley National Park, Inyo Co. External measurements (mm) were: total length, 116; length of tail, 50; length of ear from notch, 12; length of foot, 7.5; length of tibia, 21.0; length of forearms, 41.0, 41.5.

This record is within a broad void in the reported distribution of the species. It is from 183 to 432 km distant from the nearest knowns stations of occurrence:

5 mi SW Fallon, Churchill Co. Nevada (Hall 1946)

Overton, Clark Co., Nevada (Hall 1946)

Mouth of Bright Angel Creek, Grand Canyon National Park, Coconino Co., Arizona (Hoffmeister 1986)

Big Sandy Creek, Mohave Co., Arizona (Hoffmeister 1986)

Three Rivers, Tulare Co. (Grinnell 1918)

Lancaster, Los Angeles Co., (based on a discarded female bat identified by L. M. Whitelock)

Warren's Ranch, San Bernardino Co., (Grinnell 1918)

Santa Ysabel, San Diego Co. (Grinnell 1918)

Grinnell (1937) suggested that the appearance of hoary bats, *Lasiurus cinereus,* and silver-haired bats at Furnace Creek Ranch, Death Valley National Monument, in spring and fall coincided with their anticipated migratory movements, a conclusion that may be applicable as well to the present red bat record. The oasislike site, surrounded by desert, would be especially attractive to these tree-dwelling species.

Western yellow bat
Lasiurus xanthinus (Thomas 1897)

Originally described as a subspecies of *L. ega*, this insectivorous bat recently was regarded as a separate species (Baker et al. 1988; Morales and Bickham 1995) whose range reportedly extends southward from southwestern New Mexico, southern Arizona, and southern California through Baja California, western Mexico and the Mexican plateau to Nuevo Leon and Morelos.

Early locality records of this species in California include:

Palm Springs, Riverside Co. (Constantine 1946)

Cottonwood Spring, Joshua Tree National Monument, Riverside Co. (Loomis and Stephens 1964)

Pomona, Los Angeles Co. (Stewart 1969)

Borrego Springs, San Diego Co. (Bond 1970)

Fourteen additional localities in the counties of Riverside, San Bernardino, San Diego, and Imperial were reported later (Constantine et al. 1979). Including the last-mentioned report, 214 bats of this species were received for identification after rabies testing during the period 1969–1997. They represented 59 localities within the aforementioned four counties and from Los Angeles and Orange counties (Fig. 5, Appendix).

Published northernmost and westernmost Arizona records for this species are Phoenix, Maricopa Co. (Constantine 1966) and Yuma, Yuma Co. (Constantine 1966), as mapped by Hoffmeister (1986). The present report extends the known northern and western limits of the range from Phoenix to Los Angeles County as follows:

Blythe, Riverside Co., 7-XI-1980 (MVZ 181879)

Twentynine Palms, San Bernardino Co., 13-VIII-1980 (MVZ 181943)

Yucca Valley, San Bernardino Co., 25-IX-1985 (MVZ 181946)

Muscoy, San Bernardino Co., 14-IX-1992 (MVZ 186347)

Azusa, Los Angeles Co., 12-XI-1987 (MVZ 181876)

Glendale, Los Angeles Co., 27-IX-1984 (MVZ 181877).

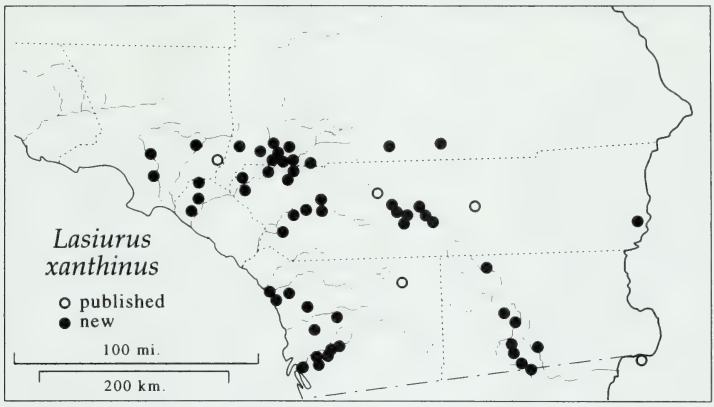

Fig. 5. Known distribution of the western yellow bat, *Lasiurus xanthinus*, in California and adjacent Arizona.

Pocketed free-tailed bat
Nyctinomops femorosaccus (Merriam 1889)

Long classified in the genus *Tadarida* (Shamel 1931), this insectivorous species recently was placed in the genus *Nyctinomops* by Freeman (1981). The species is known from southwestern Texas (Easterla 1973; Schmidley 1991) and southern New Mexico (Constantine 1958; Findley et al. 1975) through southern Arizona (Hoffmeister 1986) to southern California and southward in Mexico to Baja California, Jalisco, and Nuevo Leon, as mapped by Hall (1981) and by Kumirai and Jones (1990). In addition to the type locality at Agua Caliente [Palm Springs], Riverside Co. (Merriam 1889), the species has been reported from only two additional California localities, both in San Diego Co.: Palm Canyon, near Borrego Springs (Neil 1940) and 3 miles southeast of Suncrest, now known as Crest (Krutzsch 1944, 1945).

I have identified 47 additional bats of this species from 30 localities, 29 of which are new, from the Californian counties of Imperial, Los Angeles, Orange, Riverside, San Bernardino, and San Diego (Fig. 6, Appendix). Stations constituting the northernmost tier of these localities, proceeding from east to west, are:

Calexico, Imperial Co., 3-X-1995 (MVZ 186401)
La Quinta, Riverside Co., 13-IV-1994 (MVZ 186386)
San Bernardino, San Bernardino Co., 15-XI-1985 (MVZ 181965)
Covina, Los Angeles Co., 30-IV-1985 (MVZ 181959)
Inglewood, Los Angeles Co., 18-X-1994 (LACM 94036)

Calexico is located at the Mexico border, 190 km SSW of the nearest Arizona record at Alamo Crossing, Mohave Co. (Cockrum and Musgrove 1965). Inglewood is 182 km NW of the previously reported westernmost locality at Crest, San Diego Co.

Big free-tailed bat
Nyctinomops macrotis (Gray 1839)

This insectivorous species is known from British Columbia, Canada, in the Northwest (Cowan 1945), North Carolina on the Atlantic coast (Di Salvo et al.

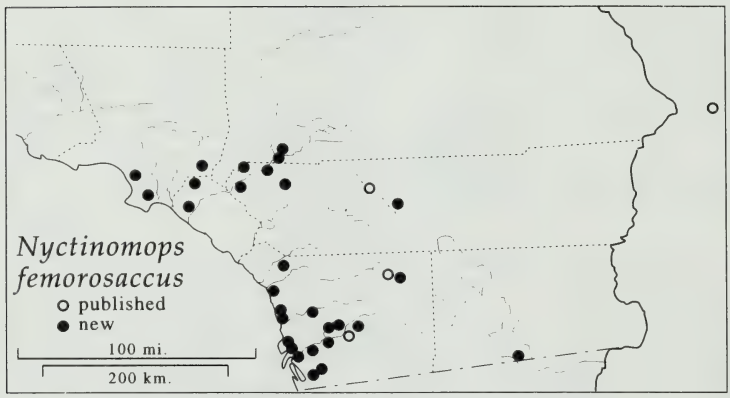

Fig. 6. Known distribution of the pocketed free-tailed bat, *Nyctinomops femorosaccus*, in California and adjacent Arizona.

1992), and the central United States southward through most of Mexico, the Caribbean islands of Cuba, Jamaica, and Hispaniola, and South America to Bolivia, northern Argentina, and Uruguay (Hall 1981; Milner et al. 1990). Reports indicate that its greatest density in the United States is in the Southwest, reports dwindling northward and eastward. For example, there are no published reports between San Diego and British Columbia, there are only two reports each from Oklahoma, Kansas, and Iowa, and no reports between Texas and the single specimen from North Carolina, whereas 36 collection localities for the species were reported from Arizona, New Mexico, and Texas (Constantine 1958, 1961a, 1961b; Hoffmeister 1986; Findley et al. 1975; Schmidly 1991).

Four of these bats were reported previously from California. No locality was given for the first bat (Shamel 1931). The other three were from San Diego, San Diego Co. (Huey 1932, 1954a; August and Dingman 1973).

The present report concerns 26 additional bats from 25 new localities in the Californian counties of Contra Costa, Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, San Mateo, and Santa Barbara (Fig. 7, Appendix). Only the northermost localities are listed below, proceeding from east to west:

El Centro, Imperial Co., 31-III-1982 (MVZ 181981)
Palm Springs, Riverside Co., 4-IV-1994 (MVZ 181986)
Pomona, Los Angeles Co., 23-XI-1987 (MVZ 181985)
Azusa, Los Angeles Co., 2-X-1997 (LACM 94037)
Burbank, Los Angeles Co., 19-XI-1987 (MVZ 181982)
Santa Barbara, Santa Barbara Co., 27-XI-1996 (MVZ 186402)
Morro Bay, San Luis Obispo Co., 18-XII-1981 (MVZ 181992)
Pacifica, San Mateo Co., 3-I-1984 (MVZ 181993)
Martinez, Contra Costa Co., 13-XI-1979 (MVZ 181980)

El Centro is 200-302 km distant from the nearest published reports to the east at Eagle Tank, Yuma Co., Arizona (Simmons 1966); 1.5 mi SE Kingman, Mohave Co., Arizona (Cockrum et al. 1996); Henderson, Clark Co., Nevada (Bradley et al. 1965). Martinez is 1279 km S of Essondale, British Columbia, the northernmost published locality. Relatively few bats of any species routinely are tested

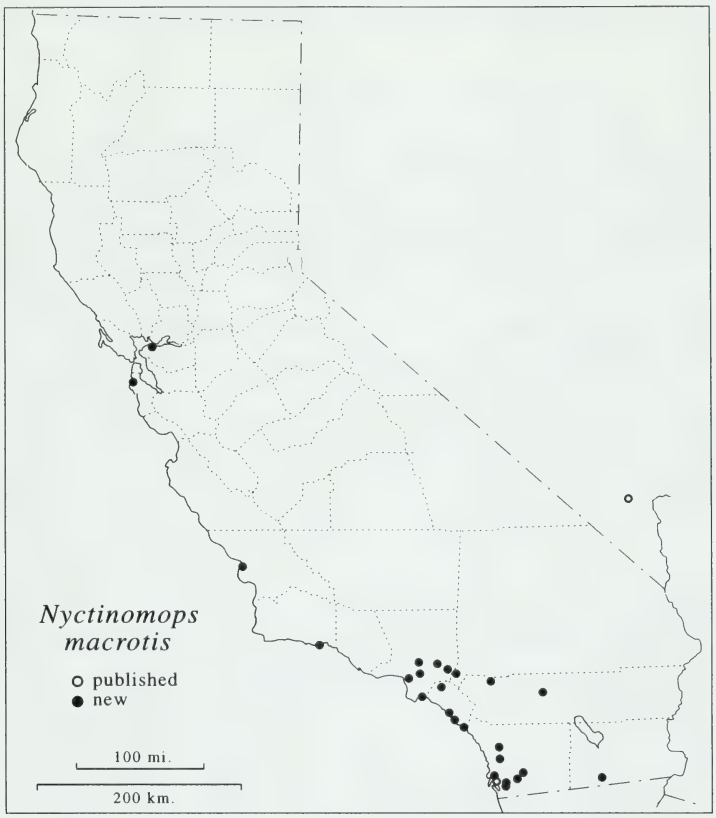

Fig. 7. Known distribution of the big free-tailed bat, *Nyctinomops macrotis*, in California and adjacent Nevada.

for rabies in Californian coastal counties north of the vicinity of San Francisco, rendering nearly meaningless the absence of specimens of this rare bat from those counties.

Western mastiff bat
Eumops perotis californicus (Merriam 1890)

This insectivorous subspecies has been reported from California to Texas southward to at least central Mexico, whereas other subspecies are recorded from northern South America southward into Argentina, (Koopman 1978). The species is also known from Cuba (Koopman 1993).

Eighty-six mastiff bats were received from laboratories between 1973 and late 1997. Forty-nine new California locality records from 13 counties resulted, which with 38 published records, are presented in Fig. 8 and the appendix. The new records generally fill voids in the known range but include the northermost locality. This species has been reported earlier at or near the Colorado River from Yuma, Yuma Co., Arizona (Cockrum 1960); 38.6 km S of Palo Verde, Imperial Co. (Eger 1977); Parker, La Paz Co., Arizona (Sanborn 1932); and Las Vegas, Clark Co., Nevada (Bradley and O'Farrell 1967). However, it has not been re-

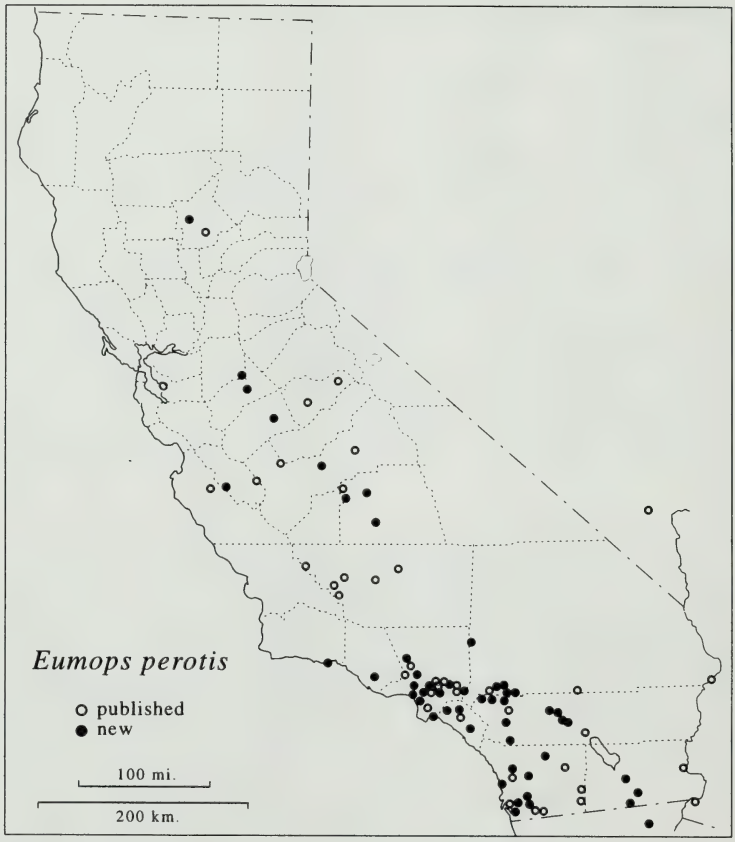

Fig. 8. Known distribution of the western mastiff bat, *Eumops perotis californicus*, in California and adjacent border areas.

ported heretofore from the Imperial Valley, Imperial Co., the Coachella Valley north of Mecca, Riverside Co. (Grinnell 1918), from elsewhere in Riverside Co. except 4 mi SW of Lakeview (Vaughan 1959), from San Bernardino Co. except Colton (Grinnell 1918; Howell 1920a) and Keys Ranch (Campbell 1931), which apparently was a sight record.

Counties represented herein from which no published records exist are Ventura, Santa Barbara, Merced, Stanislaus, and San Joaquin.

The Calexico locality (MVZ 186385) is about 33 km WNW the nearest Mexican locality record at Cerro Prieto, Baja California (MVZ 110877, a skull collected by S. B. Benson 19 April 1948), the only record of this species in Baja California.

The El Mirage, San Bernardino Co. bat (MVZ 186400) is the first specimen from the western Mojave Desert north of the transverse San Gabriel and San Bernardino Mountain Ranges, although Vaughan (1959) reported hearing the characteristic high-pitched, piercing calls of this species in the same general area.

The Durham, Butte Co. bat, a female (MVZ 186399) taken 27 February 1997, represents the northernmost specimen-substantiated locality for this species. Only 25.6 km NW of Oroville, the previous northernmost locality (Eger 1977), Durham

is 692 km WNW of Las Vegas, the next northernmost locality, and 952 km NW of Calexico.

Discussion

The samples of bats from which these locality records were derived were characterized by numerous biases that varied in space and time. In general, the bats were dead, disabled through injury or disease, or very young when discovered, and the majority had been brought home by household cats. Categorized as rabies-suspect, they were tested for that infection, especially if people or pets had been bitten or otherwise exposed.

Numbers of bats tested were proportional to the human population that discovered them, so many were from cities and towns, whereas few were from unpopulated areas. Most counties sent for taxonomic identification all of the bats they tested, but others sent bats intermittently if at all, a few counties sending only some of the bats that had proved to be infected. Relevant news stories temporarily increased public awareness and submissions for testing, and molestation of colonies or illegal poisoning of bats had the same effect due to consequent increased human and pet contacts.

The surprisingly great range extensions indicated for *M. velifer* and *L. curasoae* at first elicited thoughts that the bats may have been accidently transported by truck or other vehicle in which they had temporarily taken shelter and been closed inside. However, such possibilities seemed unlikely after the second and third *velifer* were found and after consideration that other southerly species (e.g., *C. mexicana, M. californicus*, and *L. xanthinus*) are now known or were recently known in the same general southern California areas.

Whether all of the reported range extensions from more southerly population centers reflect true changes or our emergence from a less-informed state is unclear. The increase in sampling of bats subsequent to the discovery of bat rabies in the United States in 1953 and the ever-increasing human and cat populations to collect them are undeniable. However, as evident are factors that support a concept of invasion. *Lasiurus xanthinus* is now relatively common in much of southern California, where it was undetected until 1945. That species typically lives in fan palms, with which human habitat in California has become increasingly forested for ornamental purposes, evidently encouraging this bat's range expansion from the occasional desert oasis where fan palms naturally grow in California. The majority of the migratory nectar-drinking bats (*Choeronycteris* and *Leptonycteris*) reported herein were males found during fall, corresponding to the comparable range-expansion scenario typically observed in pioneering birds, especially migratory species (Johnson 1994). *Myotis v. velifer* appears to be migratory as well, because it has been unknown during cold months along the Colorado River and in most of Arizona. Perhaps overriding influences effecting these perceived range expansions of bats from the south and southeast are climatic warming and increased summer moisture, as hypothesized by Johnson (1994) in reference to perceived avian range expansions.

Six of the 10 species of bat dealt with herein are on the State of California Department of Fish and Game's List of Mammal Species of Special Concern: *M. californicus, C. mexicana, M. velifer, N. femorosaccus, N. macrotis*, and *E. perotis*. A seventh, *L. blossevillii*, is expected to be added, and an eighth, *L. curasoae*,

will probably be included after its presence in California is anounced herein. Of these eight species, *M. californicus, C. mexicana, L. curasoae*, and *M. velifer* are generally found in caves or mines. Caves are relatively few in California, and far fewer are suitably warm for these bats. Most are visited by recreational hikers, and human population encroachment on them is increasing. The widespread closing of unused mine tunnels and shafts during hazard abatement programs, the destruction of entire mine-riddled mountains by heap-leach mining practices, and the establishment of toxic ponds and runoff by the latter must contribute to the loss and future extinction of these and other associated species of wildlife in California.

Nyctinomops femorosaccus, N. macrotis, and *E. perotis* naturally live in crevices in cliffs or in spacious caves, but they sometimes live in suitably high human structures, such as older wooden buildings, most of which have been replaced by unsuitable substitutes. Like most other bats, these molossids have suffered as targets of exterminators, especially *Eumops*, the largest and more obvious of the three.

Increasing destruction of old-growth forest is removing the attendant hollows and loose bark crevices used as shelter by *L. noctivagans*, a species also adversely affected by the increasing elimination of native forested riparian habitat, the tree foliage of which provides shelter for *L. blossevillii*.

The distributional data reported herein represent only one of several advantages consequent to identifying to species the bats tested for rabies in California or elsewhere. Taxonomic criteria, delineated through the past and continuing work of scientists in field, museum, university, or laboratory, find increasing application in disentangling the epidemiologic web of each disease that escapes from natural ecosystems into invading human populations, and rabies is no exception. Despite early opinions of leading health authorities that determining the species of each rabid bat was superfluous and that there existed only a single natural strain of rabies virus, it is now acknowledged that each of various known natural host species of bat or carnivore may be afflicted by one or sometimes more strains of rabies virus specific to that species. Host species-specific rabies virus strains were first recognized by differences in either susceptibility or in pathological reactions to the strains following inoculations of virus into panels of other mammal species (Constantine 1967a), later by monoclonal antibody techniques (Smith et al. 1986; Rupprecht et al. 1987), and recently by nucleotide sequence analysis of the viral nucleoprotein genome (Smith 1996). It is evident that a factual, comprehensive awareness of this and other zoonosis problems, now better known through the contributions of vertebrate, invertebrate, and virus taxonomists, will precede mankind's ability to develop appropriate responses. Thus, other states are encouraged to utilize the services of professional taxonomists to salvage valuable data and voucher specimens of bats currently being discarded after rabies tests.

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I am indebted to many local, county, and state personnel who have and continue to support the effort to identify the bats that have been tested for rabies in California. Although participants include animal and vector control personnel, sanitarians, public health investigators and others, my contacts have been with health department directors, physicians, public health veterinarians, and especially lab-

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Appendix. Collecting sites with geographic coordinates: new (N) and published (reference number).

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
ALAMEDA CO												
Hayward	37°40′	122°04′										74
BUTTE CO												
Durham	39°39′	121°48′										N
Oroville	39°31′	121°33′										32
CONTRA COSTA CO												
Martinez	38°01′	122°08′									N	
FRESNO CO												
Fresno	36°45′	119°46′										37
Mendota	36°45′	120°23′										37
Trimmer	36°54′	119°18′										32
IMPERIAL CO												
Brawley	32°59′	115°32′							N			N
Calexico	32°41′	115°30′							N	N		N
El Centro	32°48′	115°34′							N		N	
Heber	32°44′	116°58′							N			
Holtville	32°49′	115°23′							N			N
Imperial	32°51′	115°34′							N			
26 km NW Niland	33°23′	115°45′							N			
38.6 km S P. Verde	33°13′	114°44′										32
Seeley	32°47′	115°41′	N									
Westmoreland	33°02′	115°37′							N			
INYO CO												
Furnace Cr Ranch	36°27′	116°52′					38					
Park Village	36°31′	116°57′						N				
KERN CO												
Bakersfield	35°22′	119°01′										37
Buttonwillow	35°24′	119°28′										37
Democrat Hot Spr	35°31′	118°40′										32
Mckittrick	35°18′	119°37′										58
Sumner	36°43′	120°05′										37
10 mi NW Taft	35°14′	119°35′										32

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
LOS ANGELES CO												
Alhambra	34°06′	118°08′									N	37
Azusa	34°08′	117°54′							N			47
Bellflower	33°53′	118°07′					N					
Burbank	34°11′	118°18′									N	
Cerritos	33°52′	118°04′					N					
nr Chatsworth	34°15′	118°36′										85
Covina	34°05′	117°53′								N		47
Florence	33°58′	118°15′				N						
Gardena	33°53′	118°18′										86
Glendale	34°09′	118°15′							N			N
Harbor	33°47′	118°18′								N		
Hollywood	34°06′	118°20′										N
Huntington Park	33°59′	118°13′							N			
Inglewood	33°58′	118°21′					N			N	N	N
Iverson Ranch	34°16′	118°37′	N									
La Canada	34°12′	118°13′					N					
Lakewood	33°51′	118°08′					N					
Lancaster	34°42′	118°08′				N		N				
Long Beach	33°46′	118°11′					N				N	N
Los Angeles	34°03′	118°15′									N	37
Monrovia	34°09′	118°00′										N
Monterey Park	34°04′	118°07′										N
nr Newhall	34°23′	118°32′										85
Pacoima	34°16′	118°26′										N
Pasadena	34°09′	118°09′										37
Pomona	34°03′	117°45′							82		N	N
Santa Monica	34°01′	118°29′					N					N
Sherman Oaks	34°09′	118°27′										N
Sierra Madre	34°10′	118°03′										37
Torrance	33°50′	118°20′					N					
Valencia	34°27′	118°36′				N						N
Van Nuys	34°11′	118°27′					N					

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
MARIPOSA CO												
Mariposa	37°29′	119°58′										32
Yosemite	37°51′	119°34′										71
MERCED CO												
Merced	37°18′	120°29′										N
MONTEREY CO												
Camphora	36°27′	121°22′										87
Pacific Grove	36°37′	121°55′					37					
ORANGE CO												
Anaheim	33°50′	117°55′							N			
Brea	33°55′	117°54′							N	N		
Buena Park	33°52′	118°00′										N
Corona del Mar	33°36′	117°52′									N	
Garden Grove	33°46′	117°56′							N	N		
Irvine	33°40′	117°49′										N
Laguna Beach	33°33′	117°47′									N	
Orange	33°47′	117°51′										N
Placentia	33°52′	117°52′									N	
San Clemente	33°26′	117°37′		N								
Santa Ana	33°45′	117°52′										32
South Laguna	33°30′	117°45′									N	
Tustin	33°45′	117°50′		N								
RIVERSIDE CO												
Blythe	33°37′	114°36′				N			N			
Cathedral City	33°47′	116°28′										N
Coachella	33°41′	116°10′							N			
Corona	33°53′	117°34′							N	N		
Cottonwood Spr	33°44′	115°49′							63			
Hemet	33°45′	116°58′							N			

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
Homeland	33°45′	117°07′							N			
Indian Wells	33°43′	116°18′							N			
Indio	33°43′	116°13′							N			
La Quinta	33°50′	116°19′							N	N		N
Lakeview	33°50′	117°07′										85
March Field	33°54′	117°15′								N		
Mecca	33°34′	116°05′										37
Mira Loma	34°00′	117°31′								N		
Moreno Valley	33°53′	117°13′							N			N
Norco	33°56′	117°33′							N			N
Palm Desert	33°43′	116°22′							N			N
Palm Springs	33°50′	116°33′							18	64	N	N
Rancho Mirage	33°44′	116°25′							N			
Riverside	33°57′	117°24′							N	N	N	N
Riverside Mts	34°01′	114°31′				81						
San Jacinto	33°47′	116°57′							N			
Sun City	33°43′	117°12′							N			N
Sunnymead	33°56′	117°15′							N			
Temecula	33°30′	117°09′										N
Thermal	33°29′	116°08′							N			
Wildomar	36°50′	118°42′							N			
SAN BENITO CO												
Pinnacles N M	36°28′	121°11′										N
Silver Creek	30°30′	120°30′										29
SAN BERNARDINO CO												
Alta Loma	34°07′	117°36′							N			
Barstow	34°54′	117°01′					N					
Colton	34°04′	117°19′										37
El Mirage	34°36′	117°38′										N
Fontana	34°06′	117°26′							N			
Grand Terrace	34°02′	117°19′							N	N		
Highland	34°08′	117°12′							N			N

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
Keys Ranch	34°08′	116°10′										11
Loma Linda	34°03′	117°16′							N			
Lucerne Valley	34°27′	116°58′					N					
Muscoy	34°09′	117°21′							N			
Needles	34°51′	114°37′				37						
Ontario	34°04′	117°39′									N	
Redlands	34°04′	117°11′							N			N
San Bernardino	34°07′	117°17′							N	N		N
Saratoga Spr	35°41′	116°25′					8					
Silver Lakes	34°45′	117°19′					N					
29 Palms	34°08′	116°03′							N			
Warren's Ranch	34°08′	116°24′						37				
Whipple Mts	34°16′	114°10′	N									
Yucaipa	34°02′	117°03′			N				N			N
Yucca Valley	34°07′	116°27′							N			
SAN DIEGO CO												
Agua Caliente Spr	32°57′	116°18′					7					
Alpine	32°50′	116°46′								N		
nr Barrett Jct	32°37′	116°42′										58
Bonita	32°30′	117°02′								N		N
Borrego Spr	33°15′	116°22′	N						6	N		
Bow Willow Ra Sta	32°51′	116°14′										7
Carlsbad	33°09′	117°21′							N	N		
Chula Vista	32°38′	117°05′		N						N		N
Clairemont	32°48′	117°12′								N	N	
nr Crest	32°48′	116°52′								56		
Del Mar	32°57′	117°16′										N
Dos Cabezas	32°45′	116°08′										37

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
Dulzura	32°39′	116°47′										7
El Cajon	32°48′	116°58′							N	N	N	N
Encinitas	33°02′	117°17′								N		
Escondido	33°07′	117°05′							N		N	N
Fallbrook	33°23′	117°15′								N		
Imperial Beach	32°35′	117°07′		N								
Jamul	32°43′	116°53′										N
La Mesa	32°46′	117°01′							N		N	
Lake Hodges	33°03′	117°08′										7
Lake Murray Park	32°48′	117°02′							N			
Lakeside	32°51′	116°55′							N	N	N	
Lemon Grove	32°45′	117°02′		5								
Leucadia	33°04′	117°18′								N		
Linda Vista	32°47′	117°10′								N		
Oceanside	33°12′	117°23′			N				N			
Ocean Beach	32°45′	117°15′					N					
Palm Canyon	33°16′	116°25′								69		
Poway	32°58′	117°02′							N	N		
Ramona	33°03′	116°52′					N		N			N
Rancho Penasquitos	32°59′	117°05′									N	
San Diego	32°43′	117°09′		70			N		N	N	49	7
San Diego State U	32°47′	117°04′								N		
Santa Ysabel	33°07′	116°40′						37				
Santee	32°50′	116°58′							N	N		
Spring Valley	32°45′	117°00′		N					N		N	N
Vista	33°12′	117°15′							N			
Warner Sprs	33°17′	116°38′										N
Yaqui Well	33°08′	116°23′										7

Appendix. Continued.

Localities	Coordinates		Species*									
	N lat	W long	Mc	Cm	Lc	Mv	Ln	Lb	Lx	Nf	Nm	Ep
SAN JOAQUIN CO												
Escalon	37°48′	121°00′										N
SAN LUIS OBISPO CO												
Morro Bay	35°22′	120°51′									N	
SAN MATEO CO												
Pacifica	37°37′	122°29′									N	
SANTA BARBARA CO												
Santa Barbara	34°25′	119°42′									N	
STANISLAUS CO												
Empire	37°38′	120°54′										N
TULARE CO												
Goshen	36°21′	119°25′										N
Porterville	36°04′	119°01′										N
Three Rivers	36°26′	118°54′							37			
Traver	36°27′	119°29′										37
Woodlake	36°24′	119°06′										N
VENTURA CO												
Camarillo	34°13′	119°02′										N
Vanowen bat cave	34°12′	118°40′	48									
Ventura	34°17′	119°18′		N								

* Mc = *Macrotus californicus*; Cm = *Choeronycteris mexicana*; Lc = *Leptonycteris curasoae*; Mv = *Myotis velifer*; Ln = *Lasionycteris noctivagans*; Lb = *Lasiurus blossevillii*; Lx = *Lasiurus xanthinus*; Nf = *Nyctinomops femorosaccus*; Nm = *Nyctinomops macrotis*; Ep = *Eumops perotis*.

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Strategies of Predator Attacks on the Schooling Fish, *Selar crumenophthalmus*, in Academy Bay, Socorro Island, Islas Revillagigedo, Mexico

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Abstract.—One of the main reasons that fish form schools is that it serves to reduce the risk of being eaten. Single predators are most successful at capturing individuals not in schools. For every successful anti-predator strategy by a prey species there is usually a concomitant more successful strategy by the predators. I report here on the behavior of three species of predatory fish and two species of predatory birds toward a school of jacks, *Selar crumenophthalmus* which demonstrate that these predators use a variety of methods to obtain fish from a school.

Fish school for a variety of reasons. The behavior, dynamics, and advantages of fish schools and other similar aggregations in birds, tadpoles, and mammals have been fully described by many authors (Brattstrom 1962, 1989; Breder 1959, 1967; Cushing and Harden Jones 1968; Elliott, et al. 1977; Hamilton 1971; Major 1978, 1979; Partridge 1982; Partridge and Pitcher 1980; Seghers 1974; Shaw 1970, 1978; Webb 1980). One of the main reasons that fish school is that it serves to reduce the risk of being eaten (Breder 1967; Partridge 1982). Single predators are most successful at capturing isolated, individual prey and less successful at capturing individuals in schools (Brattstrom 1989; Major 1978, 1979). Thanks to natural selection, there usually will be a concomitant more successful strategy by the predators for every successful anti-predator strategy by a prey species! Studies on the behavior of the predator in response to schooling fish are diverse (Katzir and Chamhi 1993; Major 1978, 1979; Parish, Strand, and Lott 1989; Schmitt and Strand 1982). The outcome of any interaction between the predator and the prey fish usually depends on three factors: relative performance, maneuvering, and timing (Webb 1980). In addition, Major (1978) showed that while single predators are most successful at capturing isolated prey and less successful at capturing individuals in schools, grouped predators were more successful at capturing schooled prey. Larger predators were also able to break up schools of prey, resulting in increased numbers of prey becoming isolated. These predators then attacked these isolated individuals (Major 1978). I report here on the behavior of three species of predatory fish and two species of predatory birds preying on a school of jacks, *Selar crumenophthalmus*. This behavior shows that these predators have developed diverse strategies to prey on schooling fish.

I observed the predation of three species of fish yellowtail, *Seriola lalanderi*, California needlefish, *Strongylura exilis*, and black-tipped shark, *Carcharhinus limbatus*) and two species of birds (masked booby, *Sula dactylatra*, and great frigatebird, *Fregata minor*) on schooling jacks, *Selar crumenophthalmus*, locally called cabalito.

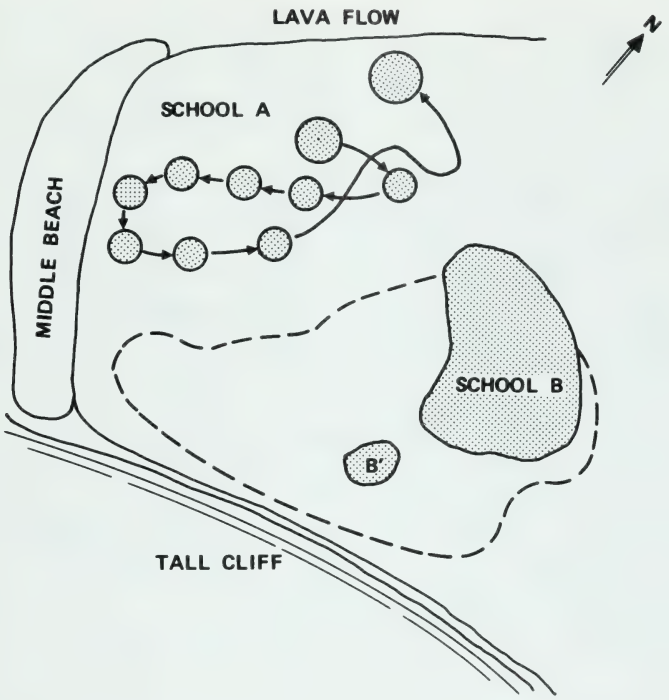

Fig. 1. Diagram of Academy Bay, Socorro Island, Mexico of cliff from which observations were made.

Observations were made from a cliff above Academy Bay, at the north end of Socorro Island, Islas Revillagigedo, Mexico. Socorro Island is 390 km SW of the southern tip of Baja California (see descriptions in Brattstrom 1955, 1963, 1982, 1990; Brattstrom and Howell 1956; Richards and Brattstrom 1959).

Observations were made throughout the day of 14 April, 1978 by me and other members of the Carnegie Museum/Sea World, 1978 Expedition to the Islas Revillagigedo. Notes and photographs (35 mm slides, 16 mm color film) were made of the schooling jacks (Fig. 1, 3). Predation by the fish was observed in the clear shallow water from the cliff (Fig. 1), predation by the birds was observed from the cliff, beach, and aboard the expedition ship anchored in Academy Bay. The temperature of the water in the bay as taken from under the ship was 25°C.

Following Breder (1959), I define a school as a behavior in which the fish are oriented in the same direction and are more or less one fish-length apart, a Pod as a group of fish that are in contact, a Pod I (or "ball") when the fish show no orientation and a Pod II when the fish show orientation.

The jacks were in two, large schools (Fig. 1), each estimated to contain tens of thousands of fish. These schools would often spontaneously change into a Pod I or Pod II. Even when the fish were oriented in one direction, the entire school or pod did not really move very far. Instead, the entire school or pod seemed to slowly "float" about the bay. School B (see Fig. 1) once divided in two and then recombined. The two main schools never joined, even though at one time they were within 3 m of each other.

The behavior of the fish in the school changed as the school approached the shore (Fig. 2; beach effect). Here the waves and/or the shallow water caused the fish nearest the shore to form a Pod II (dots in Fig. 2). This pod formation spread until the whole group was in a pod. This pod slowly moved away from the shore and switched back to a school.

Three species of predatory fish were also observed in the bay and each attempted to feed on the jacks in a different way. Groups of from two to 12 yellowtail swam around the bay always some distance from the jacks. They would circle both schools or swim back and forth in front of the beach or below the cliff. Now and then, and very suddenly, the group would turn toward the school and swim side by side straight into the school of jacks (Fig. 2, top). The fish in the school would immediately form a Pod I or Pod II at the edge of the school where the yellowtail were attacking. With the continued forward movement of the yellowtail, a ripple-like effect of school changing into pod occurred until finally all the fish were in a ball or Pod I. As the predators left, the pod would change back into a school formation as diagrammed in Fig. 2. I could not determine if the yellowtail actually caught any of the jacks, though this strategy is usually successful (Major 1978). Cooperative foraging in yellowtail has also been documented by Schmitt and Strand (1982).

Two black-tip sharks were also swimming in the bay. Now and then a shark would circle around a school of jacks, moving closer and closer to the school as it circled (Fig. 2). When the shark was about 3 m from the school, the jacks on the outer edge of the school would begin to contact each other. As the shark got closer the pod formation continued from outside toward the center until all fish were in a Pod I or ball. At that time the shark turned directly into the ball, mouth opening and closing (Fig. 2).

A single needlefish also occurred in the bay. It usually swam just below the tall cliff on which I was standing. It appeared not to notice the schooling fish, yet (and I saw this happen many times) the needlefish would turn, suddenly, directly toward the school. It swam fast, and just before reaching the school, would jump out of the water and almost sail, like a flying fish. It would land in the water in the middle of the schooling jacks with its mouth opening and closing (Fig. 2). Again, I could not determine if the needlefish was successful in obtaining a prey fish, but the density of jacks would suggest that there was a high degree of success.

The schooling jacks were also preyed upon by two sea birds. For most of the day a single frigatebird and a single masked booby flew over the bay. Both fed on the jacks by plunging down on the fish from above (Fig. 2). Both birds were successful in catching fish. The booby, for example, caught three fish in three dives over a six minute period from 1432–1458 hrs. The school/pod concentration of the prey made escape responses of the fish less effective (Katzir and Camhi 1993) and presumably therefore increased the success of the birds.

While schooling behavior in fishes may have many causes and advantages, the most documented advantage is, of course, the group effect against predators (Breder 1967; Partridge 1982). It is usually the individual, isolated or separated from the herd, flock, or school, that is taken by predators (Brattstrom 1989). Yet the mere presence of this school in this bay allowed the feeding on the school by these predators. In addition, two of the predators manipulated the school into a

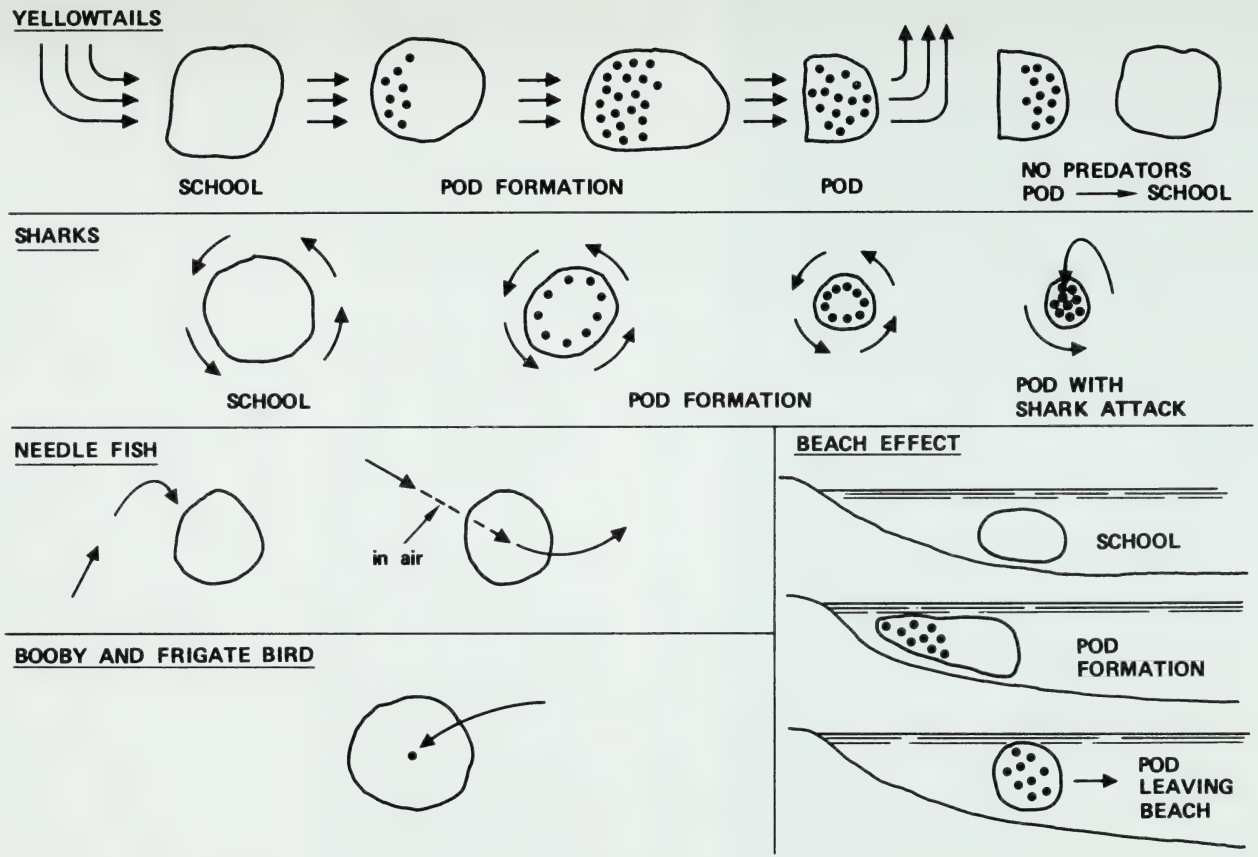

Fig. 2. Diagrams showing behavior of several predators, response of the jacks to those predators, and response of the jacks to the beach. Irregular outline shows the shape and size of the school; black dots indicate when and where the school is changing into a pod formation.

Fig. 3. Photograph of a school of jacks, *Selar crumenophthalmus*, in Academy Bay, Socorro Island, Mexico. Photograph by Robert Pitman.

pod formation where it would be expected that nearly any bite by a predator would be assured of striking a fish. Parrish, Strand, and Lott (1989) showed that while predation was highest on isolated stragglers, predation on a school of flat-iron herring, *Harengula thrissina*, due to predator strategies, was about equal on peripheral and central fish in the school. Thus, while there is an advantage to schooling by fish, there are also predators that take advantage of that schooling behavior. In addition, cooperative hunting can circumvent the schooling advantage to prey species (Schmitt and Strand 1982).

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Composition of the Helminth Community of a Montane Population of the Coastal Whiptail, *Cnemidophorus tigris multiscutatus* (Sauria: Teiidae) from Los Angeles County, California

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Abstract.—Two-hundred sixty two *Cnemidophorus tigris multiscutatus* from the San Gabriel Mountains of Southern California were examined for helminths. The helminth community consisted of two species of cestodes (*Oochoristica scelopori* and *Mesocestoides* sp.), two species of nematodes (*Pharyngodon cnemidophori* and *Physaloptera* sp.) and one species of acanthocephalan (*Moniliformis moniliformis*). The helminth with highest prevalence (15%) and greatest mean intensity (6.35) was *Pharyngodon cnemidophori. Cnemidophorus tigris* represents a new host record for *Oochoristca scelopori* and *Moniliformis moniliformis.*

The western whiptail, *Cnemidophorus tigris* Baird and Girard, 1852 ranges from north central Oregon and southern Idaho, south to Baja California and southern Coahuila, México and east to western Colorado, New Mexico and west Texas (Stebbins 1985). There are reports of helminths from *C. tigris* from Arizona (Babero and Matthias 1967; Benes 1985; Goldberg et al. 1997), California (Read and Amrein 1953; Telford 1970; Mankau and Widmer 1977), Idaho (Lyon 1986), Nevada (Babero and Matthias 1967), Texas (Specian and Ubelaker 1974a, b) and Utah (Grundmann 1959). The purpose of this paper is to report on the composition of the helminth community from a montane population of a subspecies of *C. tigris*, namely, the coastal whiptail, *C. tigris multiscutatus* Cope, 1892, from the San Gabriel Mountains of Los Angeles County, California. There are no previous reports of helminths from this subspecies which occurs in coastal California and Baja California (Stebbins 1985). Additionally, comparisons are made with helminth communities in other populations of *C. tigris.*

Materials and Methods

Two-hundred sixty two *Cnemidophorus tigris multiscutatus* from the San Gabriel Mountains, Los Angeles Co., California were examined for helminths. Two sites were sampled: 198 (112 female, 86 male) lizards were collected along California Highway 39 at 1580 m elevation and 64 (31 female, 33 male) from along California Highway 2 at 1830 m elevation. These specimens were collected in 1971 and 1974 by shooting with 22-caliber dust shot, fixed in 10% formalin and stored in ethanol. They were deposited in the Natural History Museum of Los Angeles County (LACM 111193-110931).

The body cavity was opened by a longitudinal incision from vent to throat, and the digestive tract was removed by cutting across the anterior esophagus and rectum. The lumen of the esophagus, stomach, small and large intestines and the

Table 1. Helminths from 262 *Cnemidophorus tigris multiscutatus* from the San Gabriel Mountains, Los Angeles County, California (collected 1971 and 1974).

Helminth species	Number helminths	Infected lizards	Prevalence[1] (%)	Mean abundance[2]	Site
Cestoda					
Mesocestoides sp. (Tetrathyridia)	388	3	1	1.48	Body cavity
Oochoristica scelopori	6	5	2	0.02	Small intestine
Nematoda					
Pharyngodon cnemidophori	1663	38	15	6.35	Large intestine
Physaloptera sp. (larvae)	6	3	1	0.02	Stomach
Acanthocephala					
Moniliformis moniliformis	9	3	1	0.03	Small intestine

[1] Number of hosts infected with one or more individuals of a parasite species divided by the number of hosts examined.

[2] Total number of individuals of a parasite species divided by the total number of hosts examined.

surfaces of the liver and body cavity were examined for helminths. Each helminth was initially placed in a drop of glycerol on a glass slide. Nematodes were identified from these temporary mounts. Cestodes and acanthocephalans were stained with hematoxylin and identified. Terminology usage is in accordance with Bush et al. (1997). Selected specimens were deposited in the U.S. National Parasite Collection, USNPC, Beltsville, Maryland: *Mesocestoides* sp. (87530); *Oochoristica scelopori* (87529); *Pharyngodon cnemidophori* (87531); *Physaloptera* sp. larvae (87532); *Moniliformis moniliformis* (87533).

Results

The helminth community of the San Gabriel Mountain population of *C. t. multiscutatus* was found to consist of two species of cestodes, Oochoristica scelopori Voge and Fox 1950 and *Mesocestoides* sp. (tetrathyridea only), two species of nematodes, *Pharyngodon cnemidophori* Read and Amrein 1953 and *Physaloptera* sp. (3rd stage larvae), and one species of acanthocephalan, *Moniliformis moniliformis* (Bremser 1811). The number of helminths, number of infected lizards, prevalence, mean abundance and site of infection are given in Table 1. At 1530 m elevation, (18%) 35 of 198 lizards harbored helminths, at 1580 m, (14%) 9 of 64; there was no significant difference for prevalence of helminths between elevations (chi-square = 0.33, 1 df, $P > 0.05$). Likewise, no significant difference was found between prevalence of helminths between female, (18%) 26 of 143 infected, and male, (15%) 18 of 119, lizards (chi-square = 0.31, 1 df, $P > 0.05$). It should be noted, however, that the nine *Moniliformis moniliformis* were found only at 1530 m elevation; one female and two male lizards were infected. The occurrence of *Oochoristica scelopori* and *Moniliformis moniliformis* represent new parasite records for *Cnemidophorus tigris*.

Discussion

In the present study, *C. t. multiscutatus* served as a paratenic host for three of the five species of helminths found. These species were represented by juvenile forms only; tetrathyridia of *Mesocestoides* sp., 3rd stage *Physaloptera* sp., and juvenile *Moniliformis moniliformis*. Tetrathyridia of *Mesocestoides* sp. are known

Table 2. Helminth communities (species reaching maturity) of *Cnemidophorus tigris*.

Locality	Reference	Helminth community
Arizona, Maricopa County	Benes 1985	*Oochoristica* sp.
		Alaeuris sp.
Arizona, Mohave County	Babero and Matthias 1967	*Pharyngodon warneri*
Arizona, Pima County	Goldberg et al. 1997	*Oochoristica bivitellobata*
		Abbreviata terrapenis
		Pharyngodon warneri
California, Los Angeles County	this paper	*Oochoristica scelopori*
		Pharyngodon cnemidophori
California, Riverside County	Telford 1970	*Oochoristica bivitellobata*
		Pharyngodon cnemidophori
		Skrjabinoptera phrynosoma
		Thubunaea iguanae
California, San Bernardino County	Read and Amrein 1953	*Pharyngodon cnemidophori*
Idaho	Lyon 1986	*Oochoristica bivitellobata*
Nevada, Clark County	Babero and Matthias 1967	*Oochoristica bivitellobata*
		Thubunaea cnemidophorus
Texas, Brewster County	Specian and Ubelaker 1974a	*Parathelandors texanus*
	Specian and Ubelaker 1974b	*Pharyngodon cnemidophori*
Utah	Grundmann 1959	*Oochoristica bivitellobata*
		Pharyngodon warneri

from a large number of lizard species (see McAllister 1988) and have previously been reported from *C. tigris* from California (Mankau and Widmer 1977), Arizona (Benes 1985) and Nevada (Babero and Matthias 1967). *Mesocestoides* sp. is thought to require an arthropod intermediate host (Webster 1949). Third stage larvae of *Physaloptera* sp. are commonly found in species of *Cnemidophorus* (see Goldberg et al. 1993). In North America, no species of *Cnemidophorus* is known to harbor adult *Physaloptera*. Helminths (USNPC # 80202) identified as *Physaloptera* retusa in the report by Goldberg and Bursey (1989) were found to be *Abbreviata terrapenis*. Arthropods serve as intermediate hosts (Lincoln and Anderson 1975). Mammals, especially rodents, serve as definitive hosts for *M. moniliformis*; insects are intermediate hosts (Van Cleave 1953). Unidentified acanthocephalans were reported in *C. tigris* from central Arizona by Benes (1985) and *Centrorhynchus* sp. was found in *C. tigris* from southern Arizona by Goldberg et al. (1997). These helminth species might be expected in any insectivore. *Cnemidophorus tigris* also serves as a paratenic host for another nematode, *Angusticaecum* sp. from Utah (Grundmann 1959).

Cnemidophorus t. multiscutatus served as definitive hosts for two of the five species of helminths found: *Oochoristica scelopori* and *Pharyngodon cnemidophori*. *Oochoristica scelopori* is known from a variety of North American lizards (see Goldberg et al. 1996). *Pharyngodon cnemidophori* has been reported only from teiid lizards: *C. tigris* in Texas (Specian and Ubelaker 1974b); *C. tigris* in California (as *Cnemidophorus tesselatus* in Read and Amrein 1953; Telford 1970). Other helminths for which *C. tigris* serves as a definitive host are *Oochoristica bivitellobata, Abbreviata terrapenis, Pharyngodon warneri, Parathelandros texanus, Skrjabinoptera phrynosoma, Thubunaea cnemidophorus* and *T. iguanae* (Table 2). *Cnemidophorus tigris* from central Arizona was reported to harbor *Alaeuris*

sp. and *Oochoristica* sp. by Benes (1985). We believe the identification of *Alaeuris* sp. to be incorrect and consider this instance to represent an oxyurid species, probably *Pharyngodon* sp. It is of interest to note that the helminth community for which *C. tigris* is definitive host is different in each population so far studied (Table 2). This suggests that distribution patterns of helminth species are often different from distribution patterns of hosts or potential hosts.

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Notes on the Late Prehistoric Extension of the Range for the Muskrat (*Ondatra zibethicus*) along the Ancient Shoreline of Lake Cahuilla, Coachella Valley, Riverside County, California

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In 1990, a series of archaeological excavations was conducted by the Archaeological Research Unit (ARU), University of California, as part of environmental assessments prepared in anticipation of several proposed development projects in La Quinta, California. La Quinta, located in the northwestern Coachella Valley, is 24 km (15 miles) southwest of Palm Springs in central Riverside County (Fig. 1). Three archaeological sites in La Quinta, CA-RIV-3682, CA-RIV-3144 and CA-RIV-1182, yielded collections of subfossil vertebrate remains (interpreted as food refuse) in addition to an array of cultural materials. These three archaeological sites, as well as many others in the region, are believed to represent small fishing/lacustrine resource gathering encampments located along the shore of prehistoric Lake Cahuilla (also known as Lake LaConte; see Wilke 1978). This lake filled the Salton Basin up to the Coachella Valley at various times until the latter part of the sixteenth century (Weide 1976; Wilke 1978; Figure 1). At maximum fill, Lake Cahuilla was a veritable inland sea with an estimated surface area of 1,256,550 acres (Weide 1976). The three prehistoric sites and associated subfossil assemblages are thought to date to A.D. 1300 to 1500 based on several radiometric analyses of fire-hearth samples (Arkush 1990; Yohe 1990), a period that represents the last stand of Lake Cahuilla.

The analysis of the vertebrate faunal assemblages from the three archaeological localities (conducted by the author) revealed a wide range of aquatic and terrestrial taxa, the former confined to CA-RIV-3682. A summary of taxa identified at the sites include several species of freshwater fishes (*Xyrauchen texanus, Gila* spp., *Mugil cephalus, Ptychocheilus lucius, Elops affinis*), *reptiles* (*Gopherus agassizi, Dipsosaurus dorsalis, Sceloperus* sp., *Crotalus* sp.) some birds (*Fulica americana,* cf. *Anas acuta,* Passeriformes), and numerous mammals, with the Audubon cottontail (*Sylvilagus audubonii*) and woodrat (*Neotoma* sp.) dominating the mammalian assemblage (Yohe 1990). Of particular interest among the mammals at these three sites are the remains of muskrat (*Ondatra zibethicus*). This is significant since the present range for this species is 130 km southeast of La Quinta (Cockrum 1960; Grinnell et al. 1937; Ingles 1965; Willner et al. 1980). At all three sites the *Ondatra* skeletal elements are rare, consisting of isolated mandibular and maxillary molars (n = 8; CA-RIV-3682), assorted postcrania (1 ulna, 1 radius, 1 metapodial, 2 phalanges [CA-RIV-3144]); and a partial rostrum and palate with complete molar series identified from CA-RIV-1182 (Arkush 1990).

In historic times, the range of the closest extant subspecies of *Ondatra,* the Colorado muskrat (*Ondatra zibethicus bernardi*), has been both sides of the Colorado River and the New River to the south (Cockrum 1960; Grinnell et al. 1937;

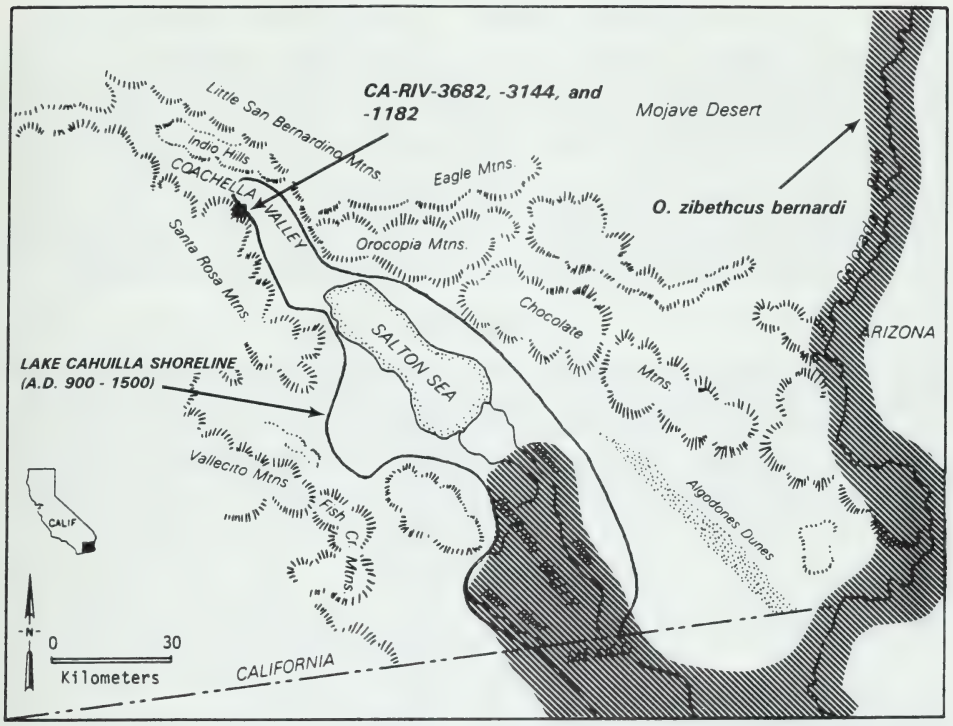

Fig. 1. Regional map of the Salton Basin and Coachella Valley, California with general locations of archaeological sites discussed in text. Dark outline represents the approximate shoreline of prehistoric Lake Cahuilla, stippling represents the current range for *Ondatra zibethicus*.

Ingles 1965; Willner et al. 1980). It is also found along irrigation canals and sloughs in the south end of the Imperial Valley. Prized for their pelts, the Colorado muskrat was hunted and trapped extensively in the southern Imperial Valley in the earlier part of the 20th century where it occurred in large numbers (Grinnell et al. 1937). According to Grinnell et al. (1937), approximately 25,000 muskrats were trapped in the Imperial Valley alone between 1919 and 1920.

The presence of late prehistoric muskrat remains in the northwestern Coachella Valley places this genus more than 100 km north of its present accepted range. Late Pleistocene/Early Holocene *Ondatra* fossils have been discovered in the eastern Salton Basin near East Mesa (Reynolds 1989), but no other paleontological occurrences in southeastern California have been reported. *Ondatra* fossils are rare in California. The only other known occurrence is a single femur from Costeau Pit (Rancholabrean-age) in the Los Angeles Basin (Miller 1971). Archaeological occurrences of the muskrat from southern California also are rare; a few *Ondatra* specimens have been recovered from San Joaquin Marsh in Newport Bay at CA-Ora-119 and -193, where they were found in both cultural and natural deposits ranging in age from ca. 6000 to 750 B.P. (Langenwalter 1986).

The course of the Colorado River, which has been naturally diverted on numerous occasions over the past several thousands of years to produce an inland sea in the Salton Basin (Wilke 1978), has provided an environmental setting

attractive to various lacustrine vertebrates in the past. The archaeological sites containing the *Ondatra* remains all appear to correspond temporally with the last stand of Lake Cahuilla (A.D. 900–1500; Wilke 1978). Muskrat remains occurring in the faunal assemblages of archaeological sites associated with ancient Lake Cahuilla suggest that these animals once frequented the cattail marshes (which were clearly present based on paleobotanical studies of human coprolite contents from numerous archaeological sites along the shoreline [see Wilke 1978; Farrell 1988]) on the northwest end of the lake, and were a source of food and possibly pelts for the prehistoric occupants of the region more than 500 years ago.

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Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

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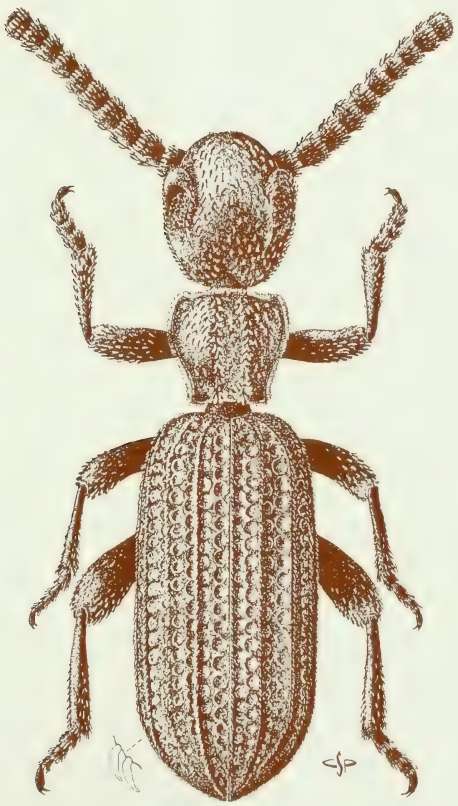
Volume 97 Number 3



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Mason Posner, University of Southern California, Los Angeles County Museum of Natural History, Fishes Section: Durham Memorial Award for Vertebrate Zoology for his paper entitled "Light Attenuating Molecules in the Lens of the Fish Eye."

Ramon M. Valencia, Biology Department, California State University, Long Beach: ARCO Award for Environmental Sciences for his paper entitled "An Assessment of the Toxicological Effects of Ingested Copper and Tungsten-Tin-Bismuth (TTB) Bullets on the California Condor (*Gymnogyps californianus*)" with A. Silverman, A. Z. Mason, D. Clendenen, and R. Risebrough.

Steve Lonhart, Department of Biology, University of California Santa Cruz: Margaret Barber Award for the Best Paper for his paper entitled "Comparison of Consumption Rates Among Benthic Invertebrate Predators."

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SAMPLE ABSTRACT & INFORMATION

MICROBIAL ACTIVITY IN THE DIGESTIVE TRACT OF THE HALFMOON, ***Medialuna californiensis.*** J. S. Kandel[1], J. R. Paterek[2] and M. H. Horn[1], [1]California State Univ. Fullerton, CA 92634 and [2]Agouron Institute, La Jolla, CA 92037.

We report the presence of a diverse microbial flora and of microbial fermentation products in the hindgut region of the halfmoon, ***Medialuna californiensis,*** a seaweed-eating fish from southern California coastal waters. Viable aerobic and anaerobic bacteria were found in all sections of the gut, but were of highest concentration (10^5–10^8/ml) in the hindgut. Microscopy revealed vibrios, spirilla, rod-shaped bacteria and flagellated protozoa in the midgut and hindgut, but primarily vibrios and rods in the stomach and foregut. Acetic, isobutyric and butyric acids, the volatile products of microbial breakdown of carbohydrates, were found only in the hindgut, as was ethanol, a nonvolatile product. These results provide the first evidence for microbial fermentation and its possible contribution to the energy supply in a north-temperate herbivorous fish.

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3. Professional

4. Contributed paper

5. Marine Biology, Microbiology, or Ichthyology

6. Kodak 35mm slide carousel projector

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Two New Stenosini Species in the Genus *Araeoschizus* LeConte from Baja California, Mexico (Coleoptera: Tenebrionidae)

Charles S. Papp

7451 Albezzia Lane, Sacramento, California 95828

The first *Araeoschizus* species from the northern part of the Baja California Peninsula was described by Blaisdell (1943) as *antennatus* collected at Punta Prieta, by E. A. Michelbacher and E. S. Ross from the California Academy of Sciences, in 1938. The most expansive collecting was done in the 1970s by F. G. Andrews, A. R. Hardy, T. D. Eichlin and M. Wasbauer from the California Department of Food and Agriculture; their material supplied most of the specimens for my revision of the genus (1981). Also, W. H. Clark, P. H. Blom, and others from the Orma J. Smith Museum of Natural History, Albertson College, Caldwell, Idaho and the University of Idaho, Moscow contributed generously to the further study of this genus.

It was a puzzle for me to classify the material William H. Clark initially collected in the broader San Agustin area. Subsequent collecting supplied more material (over 700 specimens) from this area, where, according to I. L. Wiggins (1980), four distinct plant communities meet: (1) the Californian Region, (2) the Baja California Coniferous Forests, bordered to the west by (3) a Microphyllous Desert habitat, and to the south by (4) the Sarcophyllous Desert Region (Fig. 1).

There are two recognized subspecies from this general area:

Araeoschizus antennatus clarki Papp (1989:335–337) is characterized as the more slender form. Head narrower posteriorly (more so in many specimens). Ocular lobe posterior to eye flat, not well outlined; ocular ridge shallow, with row of dense, erect to semierect squamules. Prothorax similar to *A. a. antennatus,* except the squamules on the longitudinal median ridge (creating the groove) and those along the margin of the prothorax are goldish yellow, erect and long, longer than those squamules of the ocular ridge. Elytral costae with dense row of somewhat shorter and erect squamules; rows of squamules in the elytral interspaces are much smaller, sparsely spaced and posteriorly decumbent, like those parallel with the tightly fused sutural line. Overall dark brown; prothorax slightly darker, appendages slightly lighter in color; surface shiny. Known to occur in the Rancho Santa Inez area (550 m elev.), found by W. H. Clark in foraging columns of the ant *Neivamyrmex nigrescens* Cresson.

Araeoschizus antennatus blaisdelli Papp (1989:338) with much paler, less dense and generally narrower squamules than *A. a. clarki.* The squamules at anterior half of elytra slightly thinner and somewhat roundedly pointed; in posterior half narrow and club shaped, resembling that of *A. a. antennatus.* Squamules on the longitudinal ridges of the elytra are shorter, sparser; those in the interspaces shorter and more sparsely spaced. Uniformly lighter brown; surface shiny. From the Rancho Santa Inez area (550 m elev.); also found in Valle Montevideo La Laguna Wash, 18 km W of Bahia de Los Angeles. W. H. Clark and P. E. Blom collectors.

On several collecting trips of William H. Clark and his collecting companions,

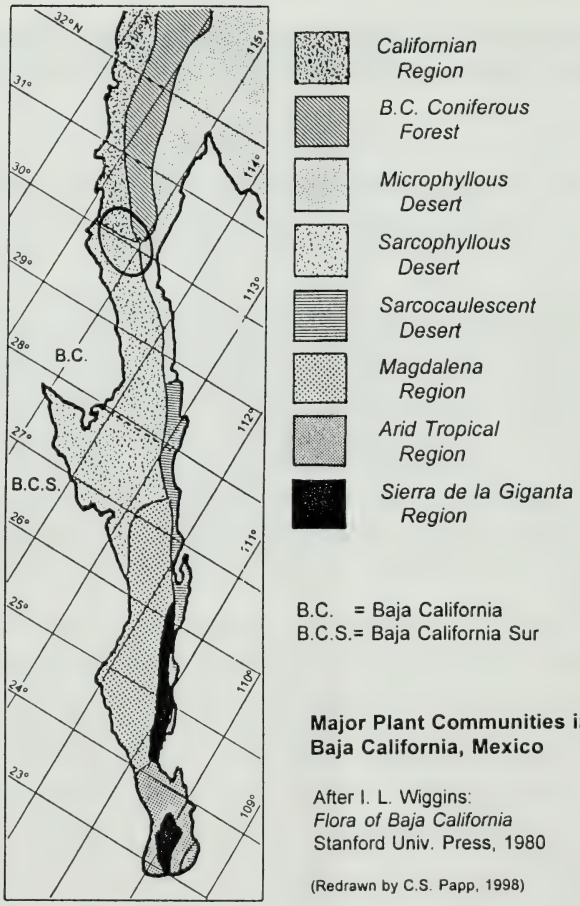

Fig. 1. The eight plant communities of Baja California. The area encircled is where four communities meet. (After I. L. Wiggins, 1980).

they were able to collect more specimens in a wider area of, as we now call it, the Four Corners (Figs. 1 and 2).

Araeoschizus agustinus Papp, n. sp. (Fig. 3)

In some respects the species resembles *squamulissimus* Papp (1981) from Diablo Dry Lake east of the Sierra de Juarez, some 50 miles W of the Colorado River delta, but the latter species is far more squamulose, head longer than broad with deeper and longer ocular groove; prothorax longer than broad and edges heavily squamulose. Dark brown, shiny throughout.

Head.—Slightly (one-tenth) longer than broad, about evenly rounded. Ocular groove shallow more so posterior to eye; ridge slightly elevated, with erect and short squamules; ocular lobe similarly squamulose. Occipital triangular impression shallow, occipital region roundly elevated. Surface minutely punctured and with forwardly decumbent short pale squamules. Frontal edge fairly straight, slightly serrated, with few longer, hair-like squamules. Eyes large, almost covering the width of the ocular groove, with 20 facets dorsally and 5 ventrally. Antennae

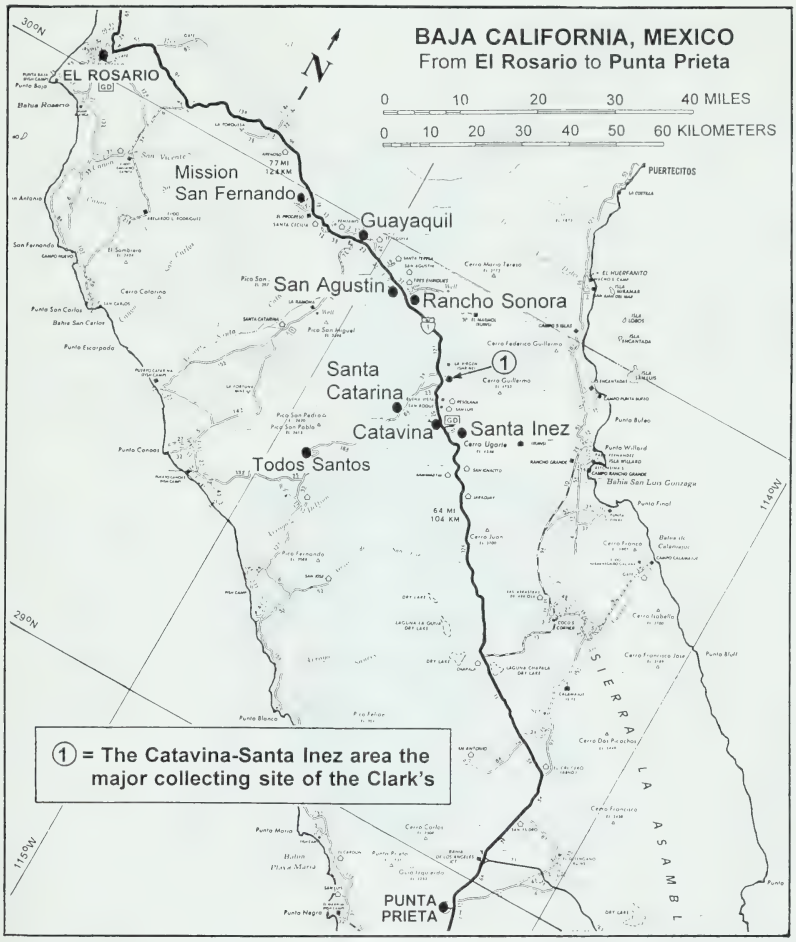

Fig. 2. The major localities mentioned in the text.

robust; segments with row of forwardly decumbent narrow squamules on anterior margins of all segments with thinner squamules on sides.

Prothorax.—About as long as broad (occasionally very slightly longer), anterior margin broader with well defined anterior pronotal angle; moderately constricted posteriorly with short pronotal angle. Longitudinal groove shallow and relatively broad; ridges with semierect narrow squamules with posterior end of ridges longer, rosette-like. Edge densely squamulose, about the size of squamules on longitudinal ridge. Surface granulose, with sporadically spaced forwardly decumbent squamules shorter than those on margin.

Elytra.—About one-third longer than head and prothorax combined. Sides in middle two-thirds parallel; shoulders broadly, posterior end more narrowly rounded. Longitudinal ridges prominent, sharply elevated, on ridge with posteriorly decumbent, curved, narrow squamules. Puncture lines very prominent; there are no secondary rows of squamules. Sutural line shallow, with a row of somewhat shorter and more sparsely spaced squamules than on longitudinal ridges.

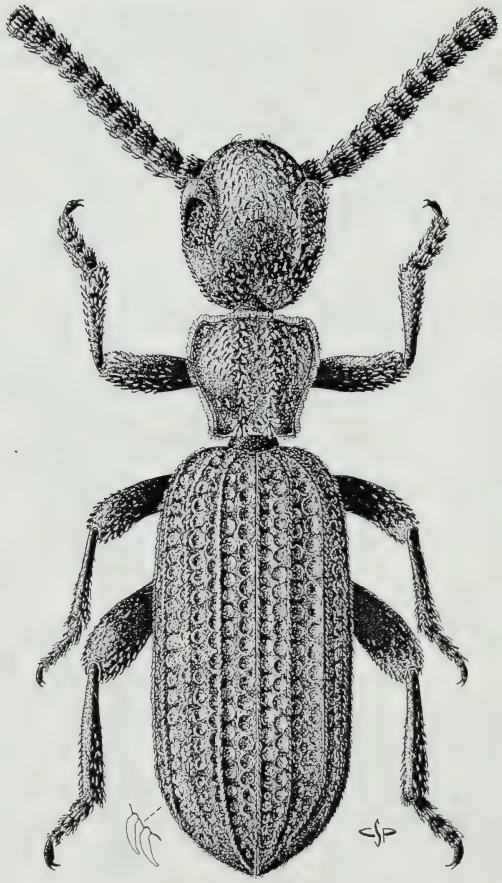

Fig. 3. *Araeoschizus agustinus* Papp, n. sp.

Underside

Head: Basal groove of sublabial plate deep; proboscis very shallow, frontal margin straight. Gular impression very shallow (almost non-existent). Surface coarsely punctate and very sparsely covered with forwardly decumbent short squamules. Prothorax: Surface with larger punctures than head; prosternal ridge evenly rounded; prosternal process narrow and more squamulose than rest of prothorax. Hind body: Surface with large, deep punctures, each puncture with a posteriorly decumbent short and thin squamula; these somewhat longer toward posterior end of body. Legs: Medium pair smallest, posterior pair largest; sparsely squamulose throughout; tarsi with somewhat longer, hair-like squamules.

Length: 4.1–4.5 mm.

Distribution

Holotype: San Agustin, elevation 580 m, in Ethylene Glycol Pitfall Trap (EGPT), VI. 16. 1991 to V. 27. 1992, William H. Clark, Paul E. Blom and Ellen M. Clark collectors. In the Orma J. Smith Museum.

Paratypes: 12 specimens from the same location (in EGPT).

Additional specimens (all in EGPT): 3 from the same location, VI. 20. 1990–

III. 10. 1991 by W. H. and Ellen M. Clark collectors.—14 from 1 mi N of Santa Catarina (Ranch), XII. 9. 1991–VIII. 3. 1992 by W. H. Clark and P. E. Blom collectors.—8 from 1.5 km SW from Guayaquil, elev. 600 m, VI. 16. 1991–V. 27. 1992 by W. H. & E. Clark, P. E. Blom and David M. Ward collectors.—10 from 10 km SE Rancho Sonora, elev. 600 m, III. 12. 1991–VII. 16. 1991 by W. H., M. H., C. J. & K. D. Clark and Jane C. Luther collectors.—2 from 9 km NW Santa Inez, VII. 17. 1991–V. 26. 1992 by W. H. and E. M. Clark collectors.—1 from 2 km E Mission San Fernando, elev. 480 m III. 12. 1991–VII. 3. 1991.—7 from 11 km ENE El Rosario, elev. 140 m VI. 22. 1991–III. 9. 1992.—1 from Valle Montevideo Wash, 18 km W Bahia de Los Angeles, elev. 380 m, III. 19. 1991–VIII. 19. 1991.—1 from Rancho La Ramona, elev. 500 m, III. 21. 1991–VII. 3. 1991.—4 from 2 km E Mission San Fernando, elev. 480 m, VII. 3. 1991–V. 20. 1992 by W. H. Clark collector.

Araeoschizus blomi Papp, n. sp. (Fig. 4)

Resembles *antennatus* Blaisdell (1943), however *blomi* can easily be differentiated by the robust antennae, the narrow posterior portion of head, the more prominent longitudinal groove of prothorax and the unique arrangement of squamules. Secondary row of squamules hardly detectable. Brown to blackish brown, shiny; also smaller.

Head.—Almost twice as long as prothorax; occipital portion narrowly rounded with prominent, yet small, occipital impression. Ocular lobes only slightly elevated, rounded, inner ocular ridge angularly placed (parallel to margin of head in *antennatus*), short, slightly elevated with prominent row of decumbent squamules. Ocular groove short, abruptly flattened posteriorly. Vertex round, evenly elevated, a slight horizontal impression between ocular lobes separates it from the nearly flat frons. Surface finely punctured, with forwardly decumbent squamules. Sides with erect longer squamules, more sparsely spaced on anterior margin. Frontal margin almost straight, with several semierect spine-like squamules. Eyes with 14–16 facets dorsally, with 5–6 facets ventrally. Antennae more robust; joints are squamulose, more densely so on anterior margin of each segment.

Prothorax.—Anterior margin slightly curved inwardly, angles more narrowly rounded than that of *antennatus,* posterior third constricted. Longitudinal groove evenly deep, one third as wide as length of posterior margin of prothorax; finely punctured. Ridges with long, erect squamules (see top insert of Fig. 4), anterior and posterior end slightly decumbent, as long as squamules on margin of prothorax, which are on sides horizontally, on anterior and posterior margin vertically erect, on the latter somewhat shorter, dense, more numerous. Surface finely punctured, with very few forwardly decumbent short squamules.

Elytra.—Slightly longer than head and prothorax combined. Shoulders narrowly rounded, sides in mid-third almost parallel. Primary cordae prominent, on frontal fourth longer, erect, other places with shorter and posteriorly decumbent, slightly club-shaped squamules. Puncture lines are prominent, punctures deep, closely spaced; secondary row of squamules between them hardly detectable, consists of short, thin, sporadically spaced, posteriorly decumbent squamules. Sutural line slightly elevated and with very short, thin, posteriorly decumbent squamules.

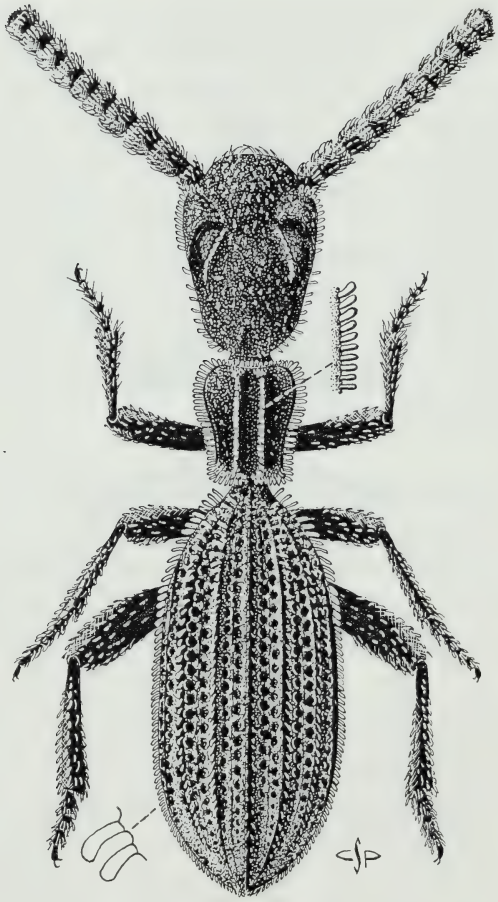

Fig. 4. *Araeoschizus blomi* Papp, n. sp.

Underside

Head: Densely punctured; with few forwardly decumbent squamules. Basal groove of sublabial plate deep, posteriorly extended into a rounded-triangularly shaped impression about half way to the very deep gular impression. Margin of sublabial plate straight; wide, proboscis long, sharply pointed, at base deeply carinate. Prothorax: Prosternal ridge highly elevated, with few, very short, erect squamules on ridge. Coarsely punctured. Prosternal process broad and with rounded posterior margin; squamulose. Hind body: With large, closely fit punctures, each puncture with narrow, posteriorly decumbent thin squamules longer than diameter of punctures. Legs: Middle pair smallest, hind pair largest; covered with relatively long narrow squamules, these thinner and longer toward tip of tibia; longer and thinner on tarsi.

Length: 3.8–4.1 mm.

Distribution

Holotype: 9 mi N of Rancho Santa Inez, elevation 550 m, in EGPT, III. 18. 1991–VII. 17. 1991, by W. H., Mary H., Cynthia J. & Caren D. Clark and James C. Luther collectors. In the Orma J. Smith Museum of Natural History.

Paratypes: 12 specimens, same location, same collectors; in the same Museum.

Additional specimens (all in EGPT): 45 from San Agustin, elevation 580 m, III. 10. 1991–VII. 16. 1991, same collectors; additional 21 specimens from the same location XII. 21. 1988–VIII. 29. 1989 by W. H. Clark collector.—2 from 2 km SE Rancho Sonora, VII. 16. 1991–V. 27. 1992, W. H. & E. M. Clark and P. E. Blom collectors.—3 from 5 km SW Guayaquil, 600 m elevation, III. 23. 1991–VIII. 3. 1991 and VII. 3. 1991–V. 27. 1992 by the same collectors.—3 from Santa Inez, III. 13. 1991–VII. 17. 1991 by W. H. and Mary H. Clark collectors; 11 specimens VII. 4. 1991–I. 4–5, 1992 by W. H. Clark and P. E. Blom collectors.

It will be interesting to see what specimens the Clarks come up with south from Santa Inez. No doubt, *antennatus* was reported in the above mentioned general area (Papp, 1981:324) 13 mi E from El Rosario, collected by G. E. & E. S. Ross and V. L. Vesterby in 1938 and later by W. H. Clark in 1978 to recently. It would be interesting to find out the distribution of this species further to the south and behind the type locality, Punta Prieta. I believe *antennatus* is the dominant species in the center two-thirds of Baja California.

In the collection of the California Academy of Sciences there is a specimen from Baja California Sur with spines on all femora and with secondary rows of squamules on elytra. The specimen was collected by S. C. Williams in an isolated area at San Migual de Comundu at 1500 ft. elevation on April 21, 1969. This area should be intensively collected. This unique specimen belongs to Group I in the key (Papp, 1981:295), the first ever collected in the southern portion of the Baja California Peninsula.

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Distribution and Taxonomic Remarks for Five Crab Species of the Family Grapsidae (Crustacea: Sesarminae and Varuninae) of the Mexican Pacific

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Abstract.—The present report updates the distribution of *Armases magdalenense* (Rathbun, 1918), *Hemigrapsus oregonensis* (Dana 1851) and *Goetice americanus* Rathbun 1923 along the Baja California coast. Previous records of *Tetragrapsus jouyi* (Rathbun 1893) to the rocky intertidal of Punta Pelícano, near Puerto Peñasco, Sonora, are rejected. These were based on misidentifications of specimens of *G. americanus*. *Tetragrapsus jouyi* is known from salt marsh areas of Guaymas, Sonora, and Bahía de Los Angeles, Baja California (new locality). The presence of *Hemigrapsus nudus* in the Gulf of California is not confirmed. It undoubtedly occurs on the west coast of the Baja California Peninsula northward to Alaska, U.S.A. An identification key to the Varuninae of the East Pacific is provided.

Resúmen.—El presente trabajo actualiza la distribución de *Armases magdalenense* (Rathbun, 1918), *Hemigrapsus oregonensis* (Dana 1851) and *Goetice americanus* Rathbun 1923. Se rechazan los registros previos de *Tetragrapsus jouyi* (Rathbun 1893) para el intermareal rocoso de Punta Pelícano, cerca de Puerto Peñasco, Sonora. Estos fueron identificaciones incorrectas de especímenes pertenecientes a *G. americanus*. *Tetragrapsus jouyi* se conoce para saladares de Guaymas, Sonora y Bahía de Los Angeles, Baja California (nueva localidad). No se confirma la presencia de *Hemigrapsus nudus* en el Golfo de California. Esta especie ocurre, con certeza, en la costa occidental de la península de Baja California y hacia norte hasta Alaska, E.U.A. Se provee una clave para identificar las especies de la subfamilia Varuninae del Pacífico Oriental.

The study of specimens collected in the Gulf of California and of others borrowed from several institutions allows us to correct and update the distribution of 5 species of grapsid crabs (1 Sesarminae and 4 Varuninae) of the East Pacific. Information presented herein update those reported by Hendrickx (1995). For each species listed, some taxonomic and ecological remarks based on the new material are presented. In addition, a comparative morphological analysis allows us to provide a key for the members of the subfamily Varuninae of the East Pacific.

Material and Methods

This study is largely based on material collected by the authors along the Baja California Peninsula and Sonora coast, north to parallel 31°N. Additional material came from the Invertebrate Collection (Crustacea) of the Scripps Institution of Oceanography, University of California, La Jolla, California (SIO) and the Invertebrate Collection of the Peabody Museum of Natural History, Yale University,

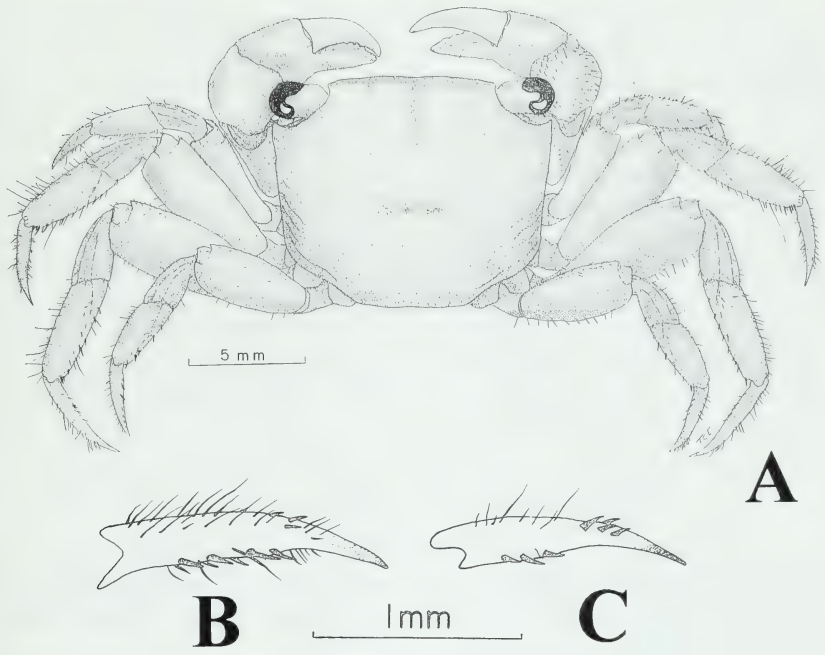


Fig. 1. *Armases magdalenense* (Rathbun 1918); A, male holotype dorsal view; B–C dactyli of the fourth walking leg (A–C from Abele 1992).

New Haven, Connecticut (YPM). The Baja California records of *Hemigrapsus oregonensis* provided by the late John S. Garth, are based on material of the Allan Hancock Foundation, from collections made primarily by the "Velero IV", "Searcher" and "The Kenyon-Williams" expeditions. This material is in the Natural History Museum of Los Angeles County (LACM). Voucher specimens are deposited in the Laboratorio de Invertebrados, Facultad de Ciencias, Universidad Autónoma de Baja California (UABC). Other abbreviations used are: Gulf of California (GC); Baja California (BC); Baja California Sur (BCS); Sonora (SON); Departamento de Investigación Científica y Tecnológica, Universidad de Sonora (DICTUS).

Taxonomic Account

Family Grapsidae MacLeay 1838

Subfamily Sesarminae Dana 1851

Armases magdalenense (Rathbun 1918)

Fig. 1A–C

Previously known distribution.—Bahía Magdalena, west coast of BCS and from Bahía Altata, Altata, Sinaloa (GC), to Agua Brava, Nayarit (Abele 1992; Hendrickx 1993, 1995; Villalobos-Hiriart et al. 1989).

Material examined.—20+ males and ovigerous females, Estuary of Mulegé River, Mulegé, BCS (GC), 30 Jul 1996.

Remarks.—Four species of the genus *Armases* Abele 1992 have been recorded along the East Pacific: *A. angustum* (Smith 1870) (Mexico to Ecuador); *A. occi-*

dentale (Smith 1870) (El Salvador to Ecuador); *A. gorei* (Abele 1981) (Peru) and *A. magdalenense* (Rathbun 1918) (Mexico), (see Abele 1992). *Armases magdalenense* can be separated from other species for its carapace (Fig. 1A), distinctly wider than long (cl/cb = 0.83), the extensor margin of the dactyl of the last walking leg is also armed with black spines (Fig. 1B–C) and the palm of the chela is smooth (Abele 1992).

The present record extends the northern distribution limit of *A. magdalenense* in the GC approximately 300 km. It is a common but inconspicuous crab along banks of estuary of the Mulegé River and its habitat agrees with that reported by Hendrickx and Salgado-Barragán (1992): under dead plants on sandy substrate, in the shade of mangrove trees above the water line. Two species of fiddler crabs, *Uca latimanus* (Rathbun 1893) and *U. crenulata crenulata* (Lockington 1877), and the grapsoid crab *Geograpsus lividus* (H. Milne-Edwards 1837) were collected in the same habitat.

Subfamily Varuninae H. Milne-Edwards, 1853

Goetice americanus Rathbun 1923

Fig. 2A–B

Previously known distribution.—GC, Bahía San Luis Gonzága, BC, and Guaymas, SON; west coast of the BC Peninsula at Bahía Tortugas (=San Bartolomé), BCS (Rathbun 1923).

Material examined.—100+ males and females, San Felipe and vicinity, BC, Puerto Peñasco, SON, Bahía de Los Angeles, BC, and Bahía Concepción, BCS, 1985–1995.

Remarks.—*Goetice americanus* is the most abundant brachyuran crab of the highest rocky intertidal of the GC. It is a common species from Bahía de Los Angeles, BC north to San Felipe, BC and Puerto Peñasco, SON, but is rare at Bahía Concepción and southward along the BC peninsula coast. Hendrickx (1994) reported *G. americanus* to Guaymas. However, his collecting efforts along the tropical Pacific (see Hendrickx 1995) and that of ours on the west coast of the BC peninsula (1985–1997) had failed to produce specimens of this species. Our findings suggest that Rathbun's (1923) record of *G. americanus* to Bahía San Bartolomé (=Bahía Tortugas) on the west coast of the BC Peninsula is extralimital.

Goetice americanus can be easily recognized by its coloration. The carapace has a marble color with a great deal of variation of white, red and gray. Ovigerous females have been collected in January, April and November.

Additional remarks on this species are under *Hemigrapsus nudus* (Dana 1851) and *Tetragrapsus jouyi* (Rathbun 1893).

Hemigrapsus oregonensis (Dana 1851)

Fig. 3A

Known distribution.—From Resurrection Bay, Alaska to Bahía San Juanico, BCS (Campos and Campos 1989); San Felipe and Bahía de Los Angeles, BC (Luke 1977).

Material examined.—14 juveniles, Estero Uno, north of Campo Don Abel, San Felipe, BC, 17 Mar 1995 (UABC); 20 males, 20 females, Laguna Percebú, San Felipe, BC, several dates (UABC); one ovigerous female, Guerrero Negro, BCS,

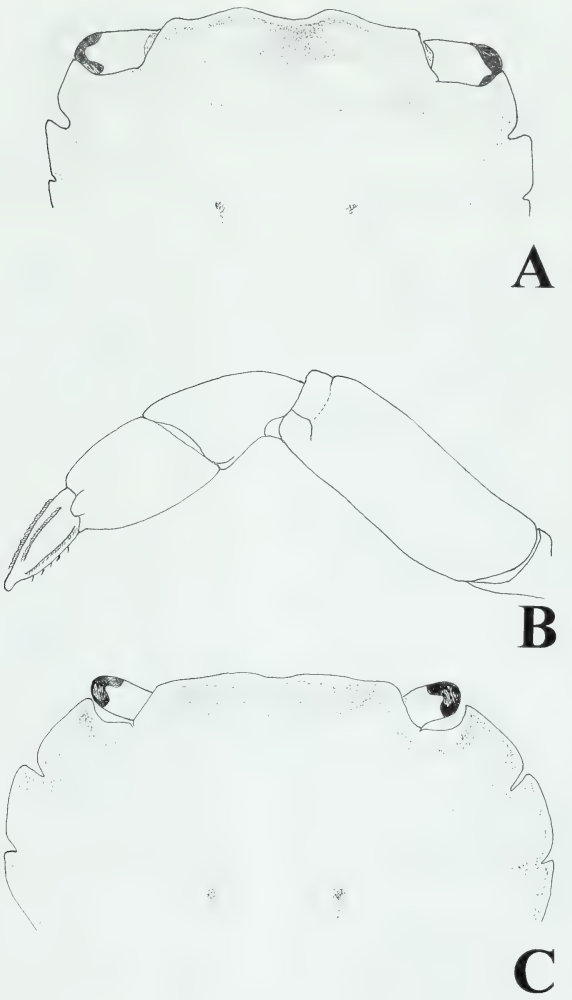


Fig. 2. A–B, *Goetice americanus* Rathbun 1923; C, *Hemigrapsus nudus* (Dana 1951). A, C, frontal view; B, dorsal face of the fourth walking leg.

21 Mar 1956 (LACM); 12 males, 12 females, Bahía Todos Santos, BC, 16 Apr 1980; 22 Nov 1996 (UABC); one male, two females, Bahía Tortugas, BCS, Jan-Apr 1987 (UABC); number and sex not available, Bahía San Juanico, BCS, 8 February 1955 (LACM).

Remarks.—See remarks under *H. nudus.*

Hemigrapsus nudus (Dana 1851)
Fig. 2C

Known distribution.—From Yakobi Island, Alaska to Bahía Tortugas, BCS. Mexico (Garth and Abbott 1980); presumably Bahía de Los Angeles (Luke 1977).

Material examined.—1 male, 1 female, Bahía Todos Santos, Ensenada, BC, no date available.

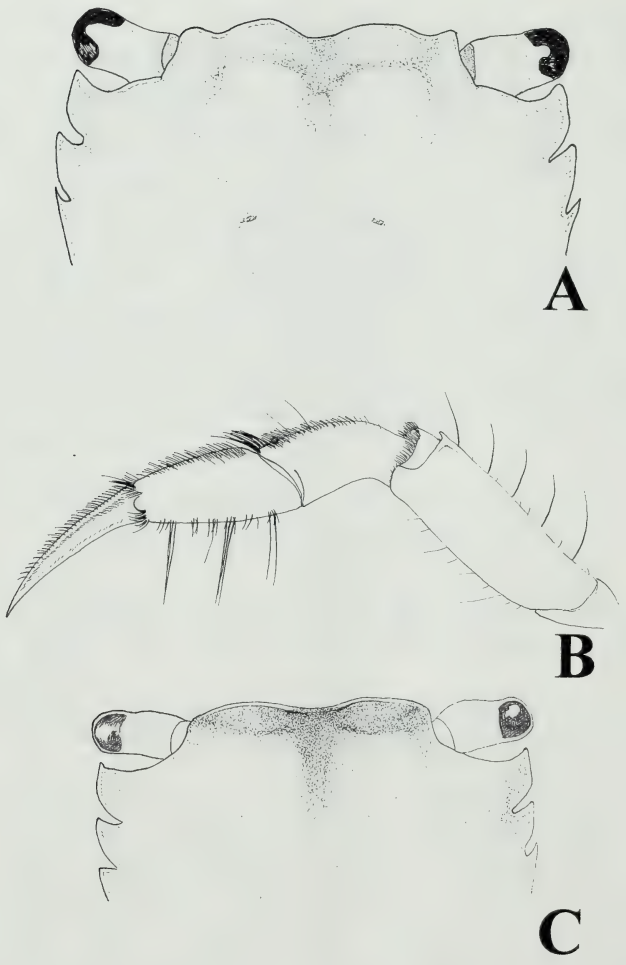


Fig. 3. A, *Hemigrapsus oregonensis* (Dana 1851); B–C *Tetragrapsus jouyi* (Rathbun 1893). A, C, frontal view; B, dorsal face of the fourth walking leg.

Remarks.—Rathbun (1923), Brusca (1980) and Garth and Abbott (1980) were hesitant about records of *H. oregonensis* and *H. nudus* in the Gulf of California. Hendrickx (1995), based on Luke's (1977) account, recorded these species to San Felipe, BC and Bahía de Los Angeles, BC respectively. The study of the material on which Luke (1977) based the records of *H. oregonensis* (SIO: C373, C375, C379, C1334) permits us to confirm the presence of this species in the upper Gulf of California. However, part of this material belongs in *Goetice americanus.* The presence of *H. nudus* is not confirmed by the present study. The only lot of specimens (SIO–C366) that supports Luke's report was not found in the SIO Crustacean Collection (C366). On the northeast Pacific coast *Hemigrapsus nudus* lives under rocks in the middle and higher intertidal. *Hemigrapsus oregonensis,* a burrower species, inhabits open mud flats, under rocks in muddy habitats, or in mats of *Enteromorpha* and beds of *Zostera,* high to low intertidal (see Garth and Abbott 1980; Bonfil et al. 1992).

Tetragrapsus jouyi (Rathbun, 1893)
Fig. 3B–C

Known distribution.—GC, Guaymas, SON (Rathbun, 1918); "quiet waters from Puerto Peñasco to Mazatlán, Espititu Santo Island and San Francisco and La Paz," Mexico (Vogel 1966; Brusca 1980).

Material examined.—40+ specimens, Bahía de Los Angeles, BC, Mar 1987 and Jul 1996.

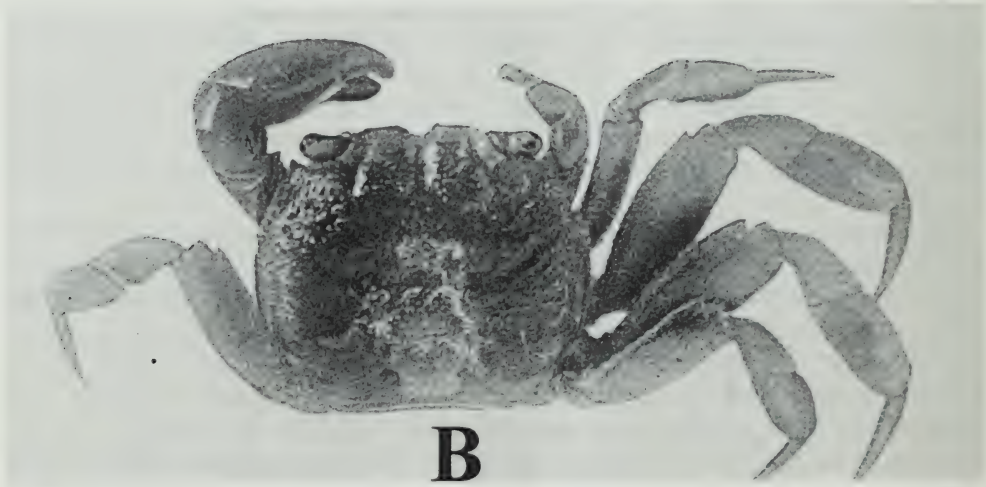
Remarks.—Tetragrapsus jouyi was originally recorded in Guaymas, SON (Rathbun 1918). Later, Vogel (1966) reported this species in Punta Pelícano, a locality close to Puerto Peñasco, SON. Brusca (1980) pointed out that it is a common and abundant species throughout the Gulf of California, living under rocks. We have examined the 25 males and 13 females (YPM 5698) on which Vogel (1966) based her report and they belong in *Goetice americanus.* The specimens reported by Brusca (1980) were not found in the Puerto Peñasco Laboratory of the DICTUS or elsewhere. Their identity remains uncertain. Brusca (in litt.) informed us that many of his records, including that of *T. jouyi,* were based solely on field identifications, which further complicates this inquiry. We believe that the grapsoid crab Brusca (1980) recorded as common and abundant under rocks along the Gulf of California is either *G. americanus, H. oregonensis* or both. Our conclusion is supported by the fact that *T. jouyi* occurs intertidally in salt marsh habitat. In Bahía de Los Angeles, it burrows among the pickle weeds (*Salicornia pacifica*) and grasses (*Distichiis spicata*). *Tetragrapsus jouyi* never occurs under rocks as do *G. americanus* and *H. oregonensis.*

Varuninae of the Mexican Pacific.—Six species of Varuninae occur along the East Pacific coast. Except for *Glyptograpsus impressus* Smith 1870 (Acapulco, Mexico to Panama) and *Euchirograpsus pacificus* Türkay 1975 (Galapagos) (see Türkay 1975; Hendrickx 1995), the remaining species *G. americanus, H. nudus, H. oregonensis* and *T. jouyi* occur intertidally in temperate and sub-tropical waters of the Mexican Pacific. They inhabit the SON and BC coast, in the upper GC and the west coast of the BC Peninsula along the Californian Province. The Varuninae of the Mexican Pacific are morphologically similar, particularly in the general shape of the carapace, third maxilliped, and chelipeds. This similarity among these species has resulted in misidentifications. A detailed morphological comparison of these species allowed us to recognize several features of the carapace, abdomen and walking legs that permit easy recognition of each species. These features have been summarized in the key below. Regarding habitat, *H. oregonensis* and *T. jouyi* prefer salt marsh areas. However, the former may also live under rocks in muddy habitats. *Hemigrapsus nudus* and *G. americanus* inhabit rocky intertidal areas.

Key to the Grapsidae-Varuninae of the East Pacific

1. First segment of male abdomen covering entire sternum between legs of last pair 5
1′. First segment of male abdomen not entirely covering the sternum between legs of last pair 2
2. Walking legs 1–4 stout, bare or with scatter, short tufts of hair setae (Fig. 2B) 3
2′. Walking legs 1–4 slender and hairy (Fig. 3B) 4

A



B

Fig. 4. A, *Euchirograpsus pacificus* Türkay 1975, male holotype; B, *Glyptograpsus impressus* Smith 1870, male dorsal view (A from Türkay 1975; B, Rathbun 1918 respectively).

3. Antero-lateral margins of carapace straight and parallel, front deeply emarginate (Fig. 2A) ..... *Goetice americanus* Rathbun 1923
3′. Antero-lateral margins arcuate, front gently emarginate (Fig. 2C) .... *Hemigrapsus nudus* (Dana 1851)
4. Front deeply emarginate, with two prominent dorsal lobes (Fig. 3A) .. .. *Hemigrapsus oregonensis* (Dana 1851)
4′. Front gently emarginate, without prominent dorsal lobes (Fig. 3C) .... *Tetragrapsus jouyi* (Rathbun 1893)
5. Carapace squarish, lateral margins straight (Fig. 4A) .... *Euchirograpsus pacificus* Türkay 1975
5′. Carapace subrotund, lateral margins arcuate (Fig. 4B) .... *Glyptograpsus impressus* Smith, 1870

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A Dietary Analysis of *Hippoglossina stomata* Eigenmann and Eigenmann, 1980 (Pisces: Bothidae) along the Western Coast of Baja California, Mexico

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Abstract.—A benthic trawl survey was conducted at depths of 38 to 218 m in September of 1990 along the western coast of Baja California on board the R/V El Puma. A dietary analysis of 67 *Hippoglossina stomata* stomachs was made in order to contribute to the knowledge of the diet of this species. Crustaceans, principally *Pleuroncodes planipes* (44.8%), and stomatopods, *Hemisquilla ensigera californiensis* (41.3%), were the most important prey items. Small crustaceans such as Malacostracea, Penaeidae, Decapoda not identified represent 5%. Fish and others were also consumed (8.4%).

The geographical and bathymetric range of the bigmouth sole, *Hippoglossina stomata* spans from Monterey Bay, California, USA to Cabo San Lucas and into the Gulf of California, México (Roedel 1953; Berdegué 1956; Eschmeyer et al. 1983) at depths from 30 to 240 m (Martínez and Ramírez 1992).

The bigmouth sole is a relatively abundant flatfish inhabiting soft sediments on the continental shelf of southern Baja California, Mexico. It could be of commercial importance (300 mm) due to the excellent quality of its meat (Berdegué 1956). Ecologically it is important since it preys on mysids, gammarideans and amphipods (Allen 1982), as well as the red crab, *Pleuroncodes planipes* (Ramírez-Murillo 1995). In turn, this species serves as food for the California sea lion, *Zalophus californianus* (Aurioles et al. 1984).

The taxonomy of the genus *Hippoglossina* was studied by De Buen (1961). Leonard (1971) studied the larvae of *Hippoglossina oblonga.* Yany et al. (1977) surveyed the food intake of *Hippoglossina macrops* in Valparaiso. Goldberg (1982) studied the seasonal spawning cycles of *Hippoglossina stomata* in Magdalena Bay, Mexico and Ramírez-Murillo (1995) examined the age and growth of *H. stomata* in Baja California. The purpose of the present study was to provide a preliminary knowledge of the food intake of *H. stomata,* off the western coast of Baja California, Mexico.

Materials and Methods

During September of 1990, a demersal trawl survey was conducted along the western continental shelf off Baja California from the northern portion of Bahia Vizcaino to the southern part of Magdalena Bay, between 24° and 28°30′N latitude and 111°30′ and 114°30′W longitude (Fig. 1).

The samples were collected by the R/V El Puma, at depths between 38 and 218 m using a shrimp otter trawl net, with a mouth opening of 21 m and 3 cm

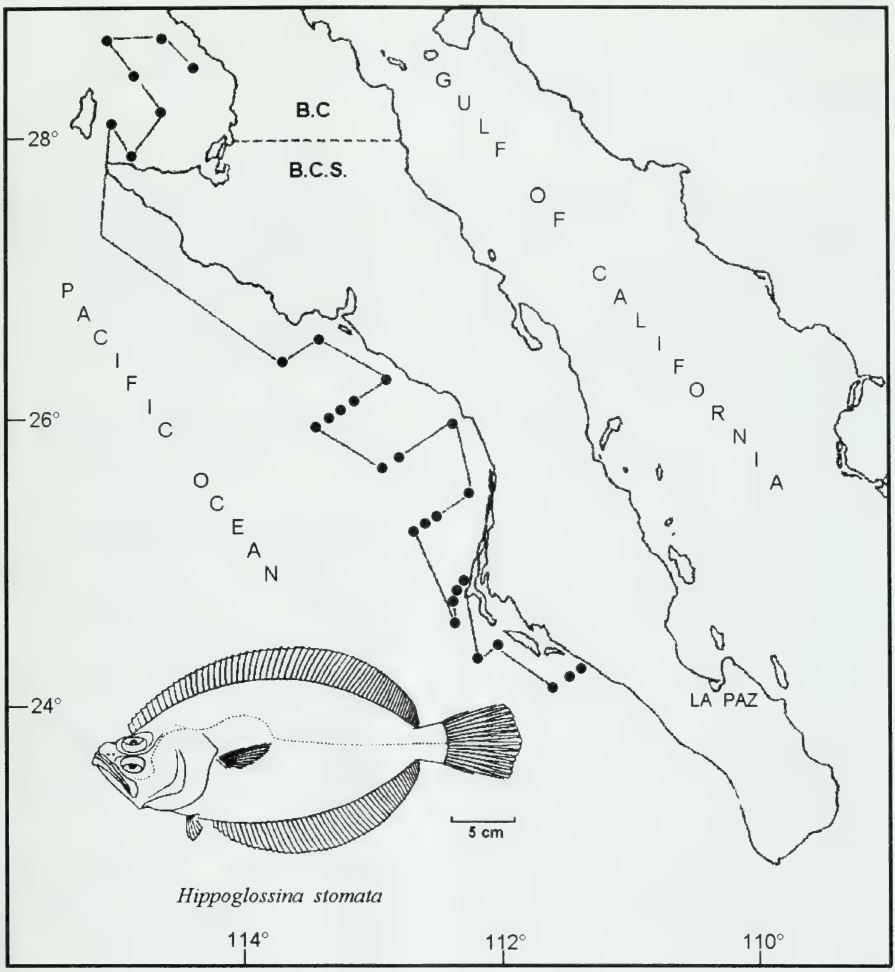

Fig. 1. Sampling stations from the EP9009 cruise, September, 1990.

mesh size. The catch was discharged on the deck and its contents counted and identified.

The *H. stomata* specimens were separated into plastic bags and fixed in 10% formalin for later transport to the laboratory.

The dietary analysis involved the following:

1. Stomachs were extracted, fixed and maintained in 10% formalin.
2. Food items were identified and counted. Those too difficult to identify were considered unknown remains and were not considered in the analysis.
3. State of digestion of prey was noted according to the method of Banner (1948a, b) and Brusca (1980).
4. Numeric, volumetric, frequency of occurrence and relative importance (IRI) of each taxon to the diet of these fish were determined using the methods of Pinkas et al. (1971): IRI = (% N + % V)(FO)

where:

N: numeric percentage; V: volumetric percentage; FO: frequency of occurrence.

Results

Of the 30 trawling operations carried out off the west coast of Baja California, *H. stomata* was present in 25 hauls (83% FO), rendering a total of 450 specimens with the greatest abundance in the area between the 24th and 27th N parallel. The minimum standard length of the fish sampled was 70 mm and the maximum 258 mm with an average of 171 mm. The main species associated with *H. stomata* were *Prionotus stephanophrys, Citharichthys xanthostigma, C. fragilis, Merluccius augustimanus,* and *Synodus lucioceps.*

Among the total of 67 *H. stomata* stomachs sampled, 11 were empty (16.4%). The remaining 56 stomachs belonged to individuals of standard length between 87 and 125 mm, with an average of 106.8 mm.

Analysis of the diet indicates that *H. stomata* feeds on a benthopelagic fauna as well as an epibenthic one. The stomachs analyzed are from relatively small and immature individuals. Crustaceans were the most important prey groups overall in the diet of this species, followed by osteichthyes and others (Table 1).

Among the 105 prey items observed, 7 families, 6 genera and 2 species could be identified by means of the analysis. The most abundant food item was the red crab, *Pleuroncodes planipes* with 45.4% V, 29.8% FO and 44.8% IRI, while in some stations the stomatopod, *Hemisquilla ensigera californiensis* was more abundant, with 29.8% V, 30.3% FO and 41.34% IRI. It does suggest some trends, when the distribution of *Pleuroncodes* is juxtaposed with the shift in dominance of the diet from *Pleuroncodes* to stomatopods.

Preference for eating the red crab, *Pleuroncodes planipes* (44.8% IRI) occurs when this species is most abundant. When *P. planipes* is absent, it is replaced in the diet by other species, like *Hemisquilla ensigera californiensis* (41.34% IRI), which live in shallower waters, and by other species, including fish, which total 13% IRI. Thus, diet diversifies based on food availability. As indicated by its large mouth and eyes and by its tooth type, *Hippoglossina stomata* feeds by settling to the bottom and waylaying its food.

Discussion

Studies of ecological communities are based on the organisms and their environmental relationship, which could be observed by analysing the feeding habits, selection of prey, transportation of energy, and nutrients. Methods and habits of food intake are highly related to internal and external morphology of the organism (Cailliet et al. 1986).

Frey (1971) states that the young flatfish settle on the bottom, eat small crustaceans, polychaetes, molluscs and fish, but, as they grow, they eat larger food items of the same groups. In this paper, more than 91.5% of the crustacean, *Pleuroncodes planipes* (44.8%) are the food intake of *H. stomata* on the Pacific coast of Baja California.

Allen (1982) found that bigmouth sole, *H. stomata* and California halibut, *Paralichthys californicus* eat mysids, gammarideans and amphipods. He did not men-

Table 1. Prey consumed by *Hippoglossina stomata* in Baja California Sur (No: number of organisms, V: volume in ml, FO: frequency of occurrence and IRI: index of relative importance).

	No.	% No.	V	% V	FO	% FO	IRI	% IRI
ARTHROPODA								
CRUSTACEA								
STOMATOPODA								
HEMISQUILLIDAE								
Hemisquilla ensigera californiensis	31	29.5	11.93	29.8	21.0	30.3	1856.0	41.34
ANOMURA								
GALATHEIDAE								
Pleuroncodes planipes	24	22.9	18.20	45.4	20.0	29.8	2035.3	44.80
AMPHIPODA								
TALITROIDEA	20	19.0	0.25	0.6	5.0	7.5	147.00	3.23
DECAPODA								
CANCRIDAE								
Cancer spp.	3	2.9	0.60	1.5	2.0	2.6	11.44	0.30
PENAEIDAE								
Sicyonia spp.	4	3.8	3.53	8.8	3.0	3.8	47.88	1.10
PALAEMONIDAE								
Palaemon spp.	8	7.6	1.60	4.0	2.0	2.6	30.16	0.70
OSTEICHTHYES								
PARALICHTHYIDAE								
Citharichthys spp.	1	1.0	1.0	2.5	1.0	1.5	5.23	0.12
Other	14	13.3	2.98	6.4	13.0	19.4	382.13	8.41
Σ	105	100	40.09	100			4334.9	100

tion, however, that they eat red crab and stomatopods as well, possibly because his samples were taken in shallower waters. Also Allen (op. cit) established 3 groups according to length: A, within the range of 6.3 to 10.0 cm; B, 11.4 to 18.9 cm and C, 19.2 to 30.8 cm. The first and second group consisted of immature fish and the main food intake were mysids and gammarideans. He also mentioned that most of the food was taken from the bottom. In the present paper the size of the fish could be compared to groups A and B, but here they prefer to eat anomurs and stomatopods.

Haig in 1955 (in Yany 1977) mentioned that *Pleuroncodes monodon* is found on the coast of Chile which spans to Ancud, and *Pleuroncodes planipes* appears on the Mexican coast off Baja California. In the study area *P. planipes* was found between 24° and 27°N latitude, although it was more abundant at 27°N (Aurioles-Gamboa 1995). According to Yany et al. (1977), *Hippoglossina macrops* has as preferred food the crustaceans, "langostino amarillo," *Cervimunida johni* in San Antonio, Punta Gallo, Laguna Verde, Concon, Quintero and Papudo; and *Pleuroncodes monodon* in Mejillones, Chile (Tomicic 1973 in Yany et al. 1977). This could indicate a close trophic relationship with similar taxa between the feeding habits of these flatfish representative of the Galatheidae family, which could be due to the distribution and abundance of these species. In either case, when the red crab is abundant in the coastal areas of Mexico and Chile, flatfish feed preferentially on this resource and on other additional groups when red crabs are scarce.

The main food source for *H. stomata* in Mexico is the red crab, *Pleuroncodes planipes,* and for *H. macrops* in Chile, the closely related *P. monodon*, due to the great abundance of these crustaceans. However, to the south of the 27th North parallel, *Hemisquilla ensigera californiensis,* which is less abundant than the red crab, is always found in the stomach content of *H. stomata* together with other species.

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SEM and Histological Evidence of Enlarged Nephridial Papillae in *Loandalia* Monro (Polychaeta: Pilargidae)

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Loandalia Monro and *Parandalia* Emerson & Fauchald are two closely allied pilargid genera. Both have a rather cylindrical body with reduced parapodia anteriorly and enlarged parapodia posteriorly. The prostomial appendages are also similar since they both lack antennae and have bifid, often biarticulated palps. Setae are also similar; notosetae are simple spines sometimes with one or two smaller companion setae dorsally and neurosetae are spinulous capillaries.

When establishing *Parandalia,* Emerson and Fauchald (1971) set the differences between both genera. *Loandalia* was restricted to the type-species (*L. aberrans* Monro), described from one specimen collected off Angola which lacks notopodial spines and has unusually well-developed branchiae in posterior setigers. *Parandalia* was separated from *Loandalia* by possessing notospines and lacking branchiae in posterior setigers. These authors noted, however, that Monro (1936) had described notospines though they did not find any when the type specimen was examined. The branchiae on Monro's specimen are unusual since they are directed ventrolaterally and free from neuropodial lobes. The original designation of these structures as branchiae has been retained by other authors.

The second species of *Loandalia* (*L. maculata*) was described by Intes and le Loeuff (1975) from several specimens collected off the Ivory Coast. They noticed the species was intermediate between both genera since it had emergent notospines and branchiae in posterior setigers. It also had an emergent ventral spine in setiger 1. These authors noted that the branchiae of *L. maculata* were smaller and started more posteriorly (setiger 50; body length 50 mm) than in *L. aberrans* (setiger 33; body length 35 mm). Salazar-Vallejo (1987) described the third species, *L. riojai,* from several specimens collected off Western Mexico. It has notospines from setiger 7 and branchiae from about setiger 22 (body length 59 mm), but it lacks emergent ventral spines in setiger 1. The fourth species, *L. salazarvallejoi,* was described by de León-González (1991), from three specimens collected off Western Baja California. It has notospines from setigers 10–13 and branchiae from setigers 31–40 (body length 67 mm); this species also lacks any emergent ventral spines in setiger 1.

Thus, in the above species the presence of emergent spines in anterior neuropodia cannot be used to set apart *Loandalia* Monro from *Parandalia* Emerson & Fauchald. Therefore, the only distinguishing feature is the presence of ventrolateral branchiae in *Loandalia* (Salazar-Vallejo 1990).

Branchiae have been employed in polychaete taxonomy to set apart closely allied genera. Although there are some arguments against branchiae as a generic character (Orensanz 1990; Fauchald 1992), its utility still has some support. However, if these enlarged ventrolateral structures were nephridial papillae instead of

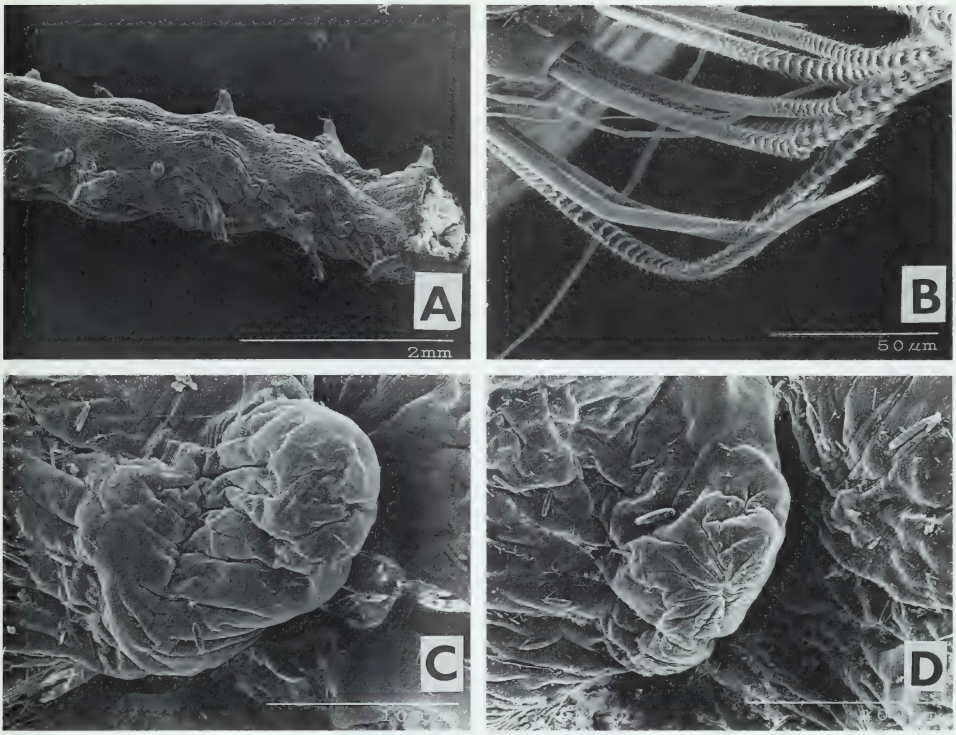

Fig. 1. SEM of a posterior fragment of *Loandalia riojai.* A. Panoramic view of the ventral portion; B. Close-up of neurosetae (the oblique thread is cotton); C. Close-up of closed nephridial papillae; D. Close-up of open nephridial papillae (scale in D is the same as in C).

branchiae, then they could not be used to separate these two genera. Since some nephridial hypertrophy is associated with reproductive activity or with sexual maturity (Schroeder & Hermans 1975), nephridial development cannot be relied upon as a discriminating feature. An early description of enlarged nephridial papillae was provided by Moore (1910:369; Pl. 31, Fig. 60) when he described *Polynoe* (?) *renotubulata.* This species was later moved to a new genus, *Bathymoorea,* by Pettibone (1967) due in part to its extended nephridial papillae. This Research Note presents SEM and histological evidence that the ventrolateral structures in *Loandalia* Monro are nephridial papillae and not branchiae.

Posterior fragments of *Loandalia riojai* Salazar-Vallejo were prepared according to standard methods for SEM and for histological analysis; some modifications were employed (Sosa-Rodríguez, 1993) from standard Hematoxylin and Eosin techniques. SEM analysis was performed in the Electronic Microscopy Unit of the Instituto de Biología, UNAM. The histological process was performed in the Laboratory of Invertebrates, Facultad de Ciencias, UNAM. All photographs were processed in the Photography Lab. of ECOSUR.

In ventral view, nephridial papillae can be seen clearly set off from neuropodium (Fig. 1A); each neuropodium is larger than the papillae and clearly distinguished by the presence of neurosetae which arise from setal bundles containing 2–3 setae each (Fig. 1B). If seen from their tip, nephridial papillae appear either

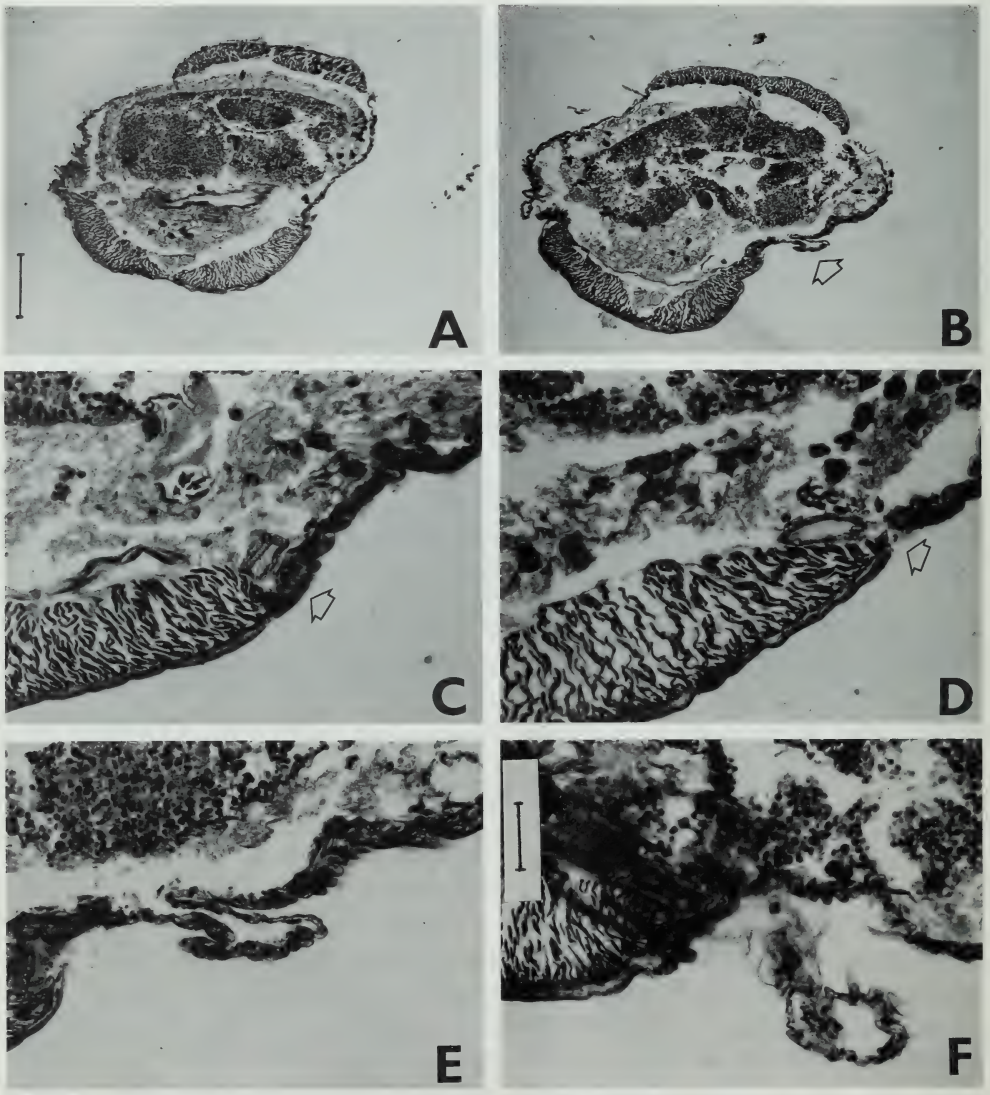

Fig. 2. Cross sections of posterior segments of *Loandalia riojai.* A. Anterior section without nephridial papillae; B. More posterior setiger with enlarged nephridial papilla (indicated by an arrow); C. Close-up of sections with nephridial ciliated funnel; D. Same, in another section; E. Close-up of a section of the enlarged nephridial papilla; F. Same, in another section (Scales: A 150 μm; F 25 μm; A and B are at the same scale; C–F are at the same scale).

closed (Fig. 1C), or have a distal nephridiopore opening (Fig. 1D). Since the distal pore might be an artifact of the dehydration process, histological inspection of the internal structure was employed to reveal whether these were branchiae or nephridial papillae.

The papillae are not seen in cross section (Fig. 2A) of anterior segments but in more posterior setigers, a clearly digitate process emerges separate from the neuropodium (Fig. 2B). Throughout the slide series, some tissue sections show a circular ciliated structure that corresponds with the nephridial funnel and is exactly

at the end of the lateral muscular bundles (Figs. 2C, D). More posterior slides show that the enlarged papillae are hollow (Figs. 2E, F). Some major blood vessels can be seen in the tissue but there are no blood vessels associated with the papillae so they cannot be branchiae.

Without true branchiae, the presence of enlarged nephridial papillae cannot be employed to separate *Loandalia* from *Parandalia.* Thus the genus *Parandalia* is a junior synonym of *Loandalia.* Since there is one species with gravid females that lacks enlarged papillae (*P. vivianneae* Salazar-Vallejo & Reyes-Barragán, 1990), these papillae might be associated only with mature males. If some mature males lack these papillae, it might represent an alternative to sperm release. Further study will be necessary on these worms' reproductive biology.

Acknowledgments

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Status of Beavers (*Castor canadensis*) in Valle de Mexicali, México

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Abstract.—To determine the current status of beavers (*Castor canadensis*) in Valle de Mexicali, Mexico, we surveyed the area in late 1995 and early 1996. We found evidence of current presence of beavers at 20 sites; 11 additional sites had evidence of past use. Most sites were along the Río Colorado. Population levels of beavers in the area are highly variable and depend on extraordinary water releases through the Río Colorado.

Resumen.—Con el fin de determinar el estado del castor (*Castor canadensis*) en el Valle de Mexicali realizamos prospecciones a finales de 1995 y principios de 1996. Encontramos evidencias de presencia actual de castor en 20 sitios; otros 11 sitios tenían evidencias de uso anterior. La mayoría de estos sitios se encontraban a lo largo del Río Colorado. Las poblaciones de castores en esta región son altamente variables y dependen de las aportaciones extraordinarias de agua del Río Colorado.

The Río Colorado and tributaries historically had abundant water and maintained large stands of willows (*Salix gooddingii*, *S. exigua*, and *S. hindsiana*) and cottonwoods (*Populus macdougalii*) along its banks and inundation flats (Wiggins 1980; Ezcurra et al. 1988). These areas supported abundant beavers (*Castor canadensis*; Stone and Rhoads 1905; MacDougal 1906; Mearns 1907; Pattie 1831). The watercourse in the area was changed extensively early in the 20th century as a requirement for agriculture. This lead from time to time to the near dissapearance of beavers from most of the area (Sykes 1937*a*, *b*). Overall, however, beavers continued to be a typical component of the region (Burt 1938; Dixon 1922; Huey 1964; Leopold 1953). Indeed, some areas that once were unsuitable for beavers developed suitable habitat as a result of management of water for agriculture (Dixon 1922; Grinnell et al. 1937; Tappe 1942). Irrigation practices and agricultural development in the Valle de Mexicali intensified in the 1960s, reducing the extent of wetlands (Mellink 1995). Also, hunting periodically substantially reduced beaver populations (Grinnell 1914; Pattie 1831).

The current status of beavers in the Mexican portion of the drainage of the Río Colorado was unknown, although it was supposed that they persisted in small numbers (Ceballos 1985; Ceballos and Navarro 1991). The purpose of this survey was to determine the extent of the presence of beavers in this area.

Methods

In October and November 1995 we visited all major water bodies in the Valle de Mexicali. As we had surveyed the Ciénega de Santa Clara in previous years,

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we did not visit it at this time. We also interviewed colleagues with ample knowledge of the Ciénega. We inspected 80 sites, and five stretches of the Río Hardy. The sites and river sections were surveyed from a car, on foot, or with a kayak. In all places, we searched for past and current evidence of use by beavers: felled trees, stumps, branches in the water, dikes, dens, and slides. On 7 February 1996, we searched for dams or dens, aboard a Cessna 182 airplane, flying over the central and northern sections of the mexican portion of the Río Colorado, and over the Ciénega de Santa Clara.

Results

We found evidence of current occupation by beavers at 20 sites, some of which had also evidence of past use; 11 other sites had evidence only of past use (Figure 1). Beavers likely occur at some other, unsurveyed, locations in the area. Beavers were found from Presa Morelos, at the northern border with the United States, to the Vado de la Carranza, the intersection of the Río Colorado with the road south out of Colonia Carranza; in one spot at the end of Canal El Caimán (formerly Canal Pescaderos), and in the Río Hardy south of Campo Mosqueda. Evidences of past use followed the same pattern, and filled in current gaps. Evidence of former use was found also at two sites at the seldom-watered Canal Médanos, and local residents informed us about past presence of beavers in Canal Álamo. This channel had been cleaned a few months prior to our visit, and no evidence of its past occupation was left.

The places that had only signs of past use by beavers reflect a current contraction of the area occupied by them, resulting from the drying of the water bodies. Also, sites with beavers to which we made succesive visits 2–3 weeks apart were rapidly drying.

Beavers were clearly associated with willows and cottonwoods, in addition to the water, as elsewhere in the Lower Colorado. On occasions beavers were present where water was limited to small stagnant pools, or to thin, shallow currents. The absence of beavers from the Río Hardy north of Campo Mosqueda, which has abundant water and where beavers were once common, can be associated with the lack of willows and cottonwoods; the only trees now present are shruby tamarisks (mainly *Tamarix pentandra*). Current existence of beaver dams, as opposed to their absence earlier in the century (Leopold 1959), is the result of the change in the type of watercourses, from a large river to small currents.

Some of the sites occupied by beavers were depressions that resulted from the construction of a protection levee on the eastern side of the Río Colorado during 1979–1981 (Sánchez-Ramirez 1990). These depressions, which can be several meters deep, were surrounded by willows and cottonwoods. In all such holes that we inspected, we found evidences of activity of beavers, either current or past.

The Ciénega de Santa Clara is a large wetland created and maintained by brine water from the Wellton-Mohawk Irrigation District, Arizona (Glenn et al. 1992). Beavers can occupy this type of marsh, when they have willows, as in Mittry Lake, Arizona (R. Henry, pers. comm.; Todd 1986). However, the Ciénega de Santa Clara has few trees, mostly restricted to the edges. Moreover, these are not the beavers' preferred trees, but western honey mesquites (*Prosopis glandulosa* var. *torreyana*), screwbean mesquites (*P. pubescens*), and tamarisks (*Tamarix ra-*

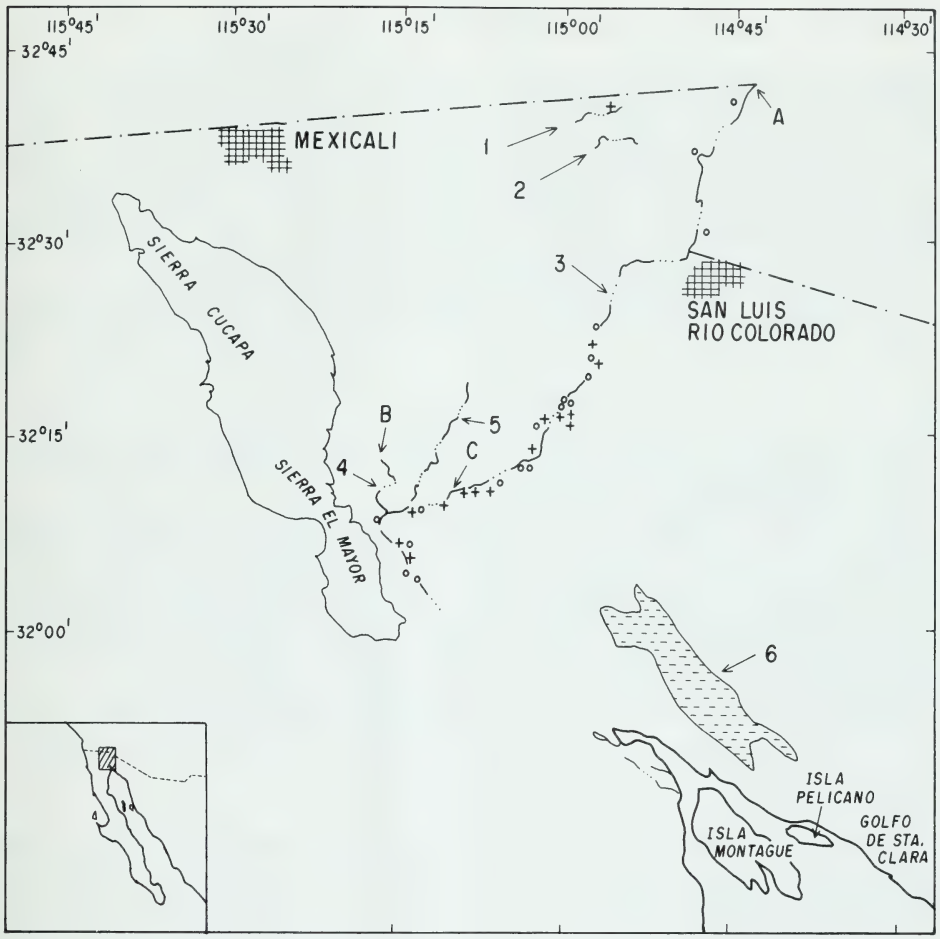

Fig. 1. Sites with beaver activity in the Valle de Mexicali, México. Circles represent beaver presence in October–November 1995. Plus signs, sites with evidence of past use by beavers. Numbers indicate waterbodies, and letters, specific locations: 1 = Canal Médanos, 2= Canal El Álamo, 3 = Río Colorado, 4 = Río hardy, 5 = Canal El Caimán (formerly Canal Pescaderos), 6 = Ciénega de Santa Clara, A = Presa Morelos, B = Campo Mosqueda, and C = Vado de la Carranza.

mosissima) (Zengel et al. 1995), which explains why neither we nor colleagues who have worked in the area have seen any evidence of beavers.

In two cases, beavers had cut stems of young tamarisks, and in two sites they seemed to be relying exclusively on tule roots (*Scirpus americanus*). Tappe (1942) considered that tules could be a more important food than commonly considered. We found them to be used rarely, and in one of the sites with heavy use of tules, beavers had been using willows until the drying of the steep-sided pool they lived in left such trees out of reach. Tules seemed, therefore, to be an emergency food.

Some people in the area eat beavers on occasion, but this does not seem to happen often. In two places, beavers were a nuisance, as they were felling trees that had been planted or were being cared for. Rather than killing the beavers, the people in charge protected the trees with old barrels and salvaged metal.

Discussion

Once control of water for agriculture began, flow in natural watercourses was reduced and the courses themselves suffered major changes. Beavers followed these changes, and some locations where beavers have been found were suitable only as a result of watercourse management. The locality of the only museum specimen from the region of which we are aware, and the locations reported by Dixon (1922), Grinnell et al. (1937), Leopold (1953), and Tappe (1942), and three of our sites were all in such newly developed riparian habitat.

The completion of Hoover Dam (in 1935) and Glenn Canyon Dam (in 1963) caused a severe reduction in water flow through the Río Colorado, and an accordingly severe reduction in populations of beavers in the Valle de Mexicali. Before 1960, beavers were locally abundant, but even then they suffered fluctuations due to dry periods, as in 1934 (Tappe 1942). Between 1960 and 1978, water in the Río Colorado south of the border was extremely scarce, and the beaver population surely was reduced.

Since 1978, there have been some important flow events in the mexican portion of the Río Colorado. These flows, especially the one resulting from the 1982–1983 El Niño Southern Oscillation (ENSO) event, promoted the development of riparian vegetation and an increase in the beaver population along the Río Colorado. Elsewhere, waterways that are usually dry (the Álamos and the Médanos, for example) received plenty of water at this time and, also, beavers.

Information on the Río Hardy's water history is difuse. During 1960-1978, it seems to have had rather stable, deep water, as the area north of Campo Mosqueda does today. Since 1947, a naturally formed dam near the entrance of the river to the Gulf of California caused the development of a large wetland, the Río Hardy marsh (J.M. Payne, pers. comm.). At least the northern section of this marsh had abundant willows and cottonwoods. The 1982-1983 ENSO caused the flooding of a vast area below the protection levee and created a large wetland that joined the Río Hardy marsh. A large community of willows and cottonwoods developed, and, according to riverside inhabitants, beavers were abundant. However, the intense flows of the mid-1980s also eroded the dam (J.M. Payne, pers. comm.), and when water flow ceased the marsh drained. Later on, the water level in the Río Hardy dropped as well.

Water flow was negligible during 1989–1992, but the 1992–1993 river discharges revived some beaver colonies. At the time of our survey, the pools in the river were drying once more; some colonies had disappeared, and others were drying rapidly. In November 1995, water levels in the Río Hardy were lowering rapidly and only a few beavers remained. Photographs take by us in 1994 contrast with the 1995 condition. However, during the aerial reconnaissance of February 1996, the Río Hardy seemed to have a higher water level than during the previous autumn.

When large amounts of water are released into the Río Colorado they can destroy existing beaver dams and carry animals away, sometimes for great distances. During the 1982-1988 flows, beavers were seen by the fuel dock at the Estero de Santa Clara, and one was captured on the sandy seashore of Golfo de Santa Clara, in the Gulf of California (R. Pita and M. J. Sánchez, pers. comm.).

These animals were a distance of about 70 Km from the closest colony at that time, across unsuitable habitat.

Although numbers of beavers in the Valle de Mexicali fluctuate dramatically and often approach extirpation, it is difficult to give them a legal risk status. The local subspecies (*C. c. frondator*, after Hoffmeister 1986) is widespread and has healthy populations in adjacent areas in the United States, where beavers are often considered a nuisance, and are controlled accordingly. There is no management plan for beavers in the valle de Mexicali, and the conservation of the habitat, in this area is fortuitous and completely marginal to agricultural production. Currently, beaver habitat is created mostly by rare extraordinary water releases through the Río Colorado.

Acknowledgments

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Re-occurrence of the Threebanded Butterflyfish, *Chaetodon humeralis* (Chaetodontidae), with Notes on its Distribution in Southern California

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The threebanded butterflyfish, *Chaetodon humeralis* Günther 1860, is an eastern Pacific endemic species whose range has been reported as northern Chile to San Diego, California, reaching the Galápagos and Cocos Islands (Miller and Lea 1972, Grove and Lavenberg 1997). It is easily distinguishable from the three other chaetodontid species, *C. falcifer, Johnrandallia nigrirostris*, and *Forcipiger flavissimus*, found in the eastern Pacific and cannot be confused with any Indo-West Pacific species. Two juvenile specimens are herein reported from southern California.

On 1 November 1997, Hugh Khim, a student at the University of California, San Diego, was free diving at 10 m along the wall of the underwater canyon in the La Jolla marine reserve. While observing other juvenile fish hiding along the one-meter high siltstone wall, he discovered a juvenile threebanded butterflyfish, approximately 4 cm total length (TL). This fish was found some three weeks later by Khim and Robert Snodgrass who videotaped it; it had not moved from its original location. Water temperatures in La Jolla at this time and during the preceding weeks were above 20°C, even at depths exceeding 20 m (R. McConnaughey, pers. comm.).

In King Harbor, Redondo Beach, California, on 12 December 1997, while conducting routine ichthyotransects with Matthew Craig, Daniel Pondella of the Vantuna Research Group (VRG) at Occidental College observed a solitary threebanded butterflyfish at the end of the west breakwater (latitude 33°50.5 N, longitude 118°23.7 W). That day on a subsequent dive it was found at the same location and captured with a hand net. The depth of capture was 10 m and the water temperature was 17.3°C, the ambient temperature of Santa Monica Bay at the time. This specimen, 46.5 mm TL, was photographed (Fig. 1), preserved and given to the Marine Vertebrates Collection at the Scripps Institution of Oceanography in La Jolla (SIO 98-23).

The last verified collection or known observation of *C. humeralis* in California was during a warm-water period approximately 140 years ago (Hubbs and Rechnitzer 1958). During the Pacific Railroad Survey, Lt. W. P. Trowbridge collected two specimens from San Diego (USNM 3170); however, these fish were not catalogued until after Girard's work on these collections (1854; 1858) and were not included in books of California fishes (Barnhart 1936, Roedel 1948, 1953). Hubbs and Rechnitzer (1958, p. 279) note:

Fig. 1. Left lateral view of the threebanded butterflyfish, *Chaetodon humeralis*, (38.6 mm SL, SIO98-23) captured in King Harbor, Redondo Beach, California on December 12, 1997. Photograph by Daniel J. Pondella, II.

> The low catalog number (3170) indicates that the specimens were in fact entered in the collection nearly 100 years ago. Lt. W. P. Trowbridge was one of the most effective of the West Coast collectors on the Pacific Railroad Surveys. Somehow the species escaped inclusion in Girard's reports on the fishes collected by these surveys. Presumably the specimens came to light after the bulk of the collections had been studied and cataloged, for the number is higher than those recorded for the species reported by Girard. In this connection it may be noted that Girard (1858: 338) referred to other specimens from San Diego that had become "mislaid in the moving of the Smithsonian collections from one end of the building to another a few months since." Some slight doubt regarding the validity of the San Diego record can not be dispelled, but we believe that *C. humeralis* is to be added to the list of tropical fishes that occurred at San Diego during the warm period a century ago.

A trip by Matthew Craig to the National Museum of Natural History found the specimens were catalogued as described by Hubbs and Rechnitzer (1958) with the locality listed simply as "San Diego". The specimens (68.9, 89.2 mm TL, Table 1) were in good condition. The two fish observed in 1997 are fairly small, allowing inferences into settlement processes. Two possibilities are that they either recruited from the ichthyoplankton or rafted into these reefs. The USNM specimens are much larger than the 1997 specimens.

Although previously collected as far north as the San Benito Islands (SIO 84-

Table 1. Counts and measurements for the three museum specimens of threebanded butterflyfish, *Chaetodon humeralis,* from southern California. Lengths given in millimeters.

	Specimens		
Counts and measurements	SIO98-23	USNM3170	USNM3170
Standard length	38.6	59.9	75.9
Total length	46.5	68.9	89.2
Dorsal fin elements	XIII, 20	XIII, 18	XIII, 19
Anal fin elements	III, 17	III, 16	III, 16
Lateral line scales	32	34	35
Pectoral rays (l)	16	17	16

227), the typical northern range does not extend past Magdalena Bay (*eg.* SIO 62-105, SIO 64-55 and R. N. Lea, pers. comm.). The specimen found in King Harbor, Redondo Beach, California represents the known northern limit of this species, an extension of some 150 kilometers from the historic San Diego locality.

Much attention has been given to the warming trends of coastal waters along our coasts of the Americas beginning in the mid 1970's (Hayward 1997) and recently exasperated by the 1997-98 major El Niño Southern Oscillation (ENSO) event. It is probable that the recruitment of these two juvenile individuals is related to this event.

Various expatriated fishes to the Southern California Bight with the northern limits of their ranges normally at Magdalena Bay, or occasionally at the San Benito Islands, have been noted since the shift from Oregonian dominated fauna to a San Diegan fauna beginning with the 1978-79 ENSO (*eg.* Brooks 1987, Lea and Fukuhara 1991, Lea and Rosenblatt 1992, Lea and McAlary 1994, Lea and Walker 1995, Pondella 1997). The long-term success of these individuals and the continued presence of these species in the Southern California Bight are uncertain. However, as indicators of environmental change (Radovich 1961, Mearns 1988, Stephens et al. 1988) the recruitment of tropical and subtropical (Panamic) species in the temperate waters of southern California is strong evidence of the current ENSO strength.

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The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

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Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

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